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## **NO-STOP 60 FSW WET AND DRY DIVES USING AIR, HELIOX, AND OXYGEN-NITROGEN MIXTURES**

**Data Report on Projects 88-06 and 88-06A:  
"Improved Decompression Procedures for Free-Swimming Divers"**

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# **NO-STOP 60 FSW WET AND DRY DIVES USING AIR, HELIOX, AND OXYGEN- NITROGEN MIXTURES.**

## **DATA REPORT ON PROJECTS 88-06 AND 88-06A:**

### **“Improved Decompression Procedures for Free-swimming Divers”**

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## Improved Decompression Procedures for Free-swimming Divers II

### A. Description of project 88-06

#### 1. Nature of this report

The purpose of this report is to provide access to experimental laboratory data involving human decompression exposures that have not been published and thus are not presently available for analysis by Navy and other researchers. As such this is only a report of the data, not a writeup of the experiment.

This report covers the project entitled "Improved Decompression Procedures for Free-swimming Divers II." This was carried out under protocol numbers 88-06 and 88-06A and includes results of some 307 manned chamber dives under various conditions. Project 88-06A represents a modification and regrouping of the original 88-06 project, dropping some of the original objectives and refining others. Project 88-06 was approved on 1988 May 2 and 88-06A on 1988 September 16 by the Naval Medical Research Institute. Principal Investigator was CAPT E.D. Thalmann.

The project is labeled with "II" because it follows earlier projects 88-01 and 88-03 which had the same title and similar objectives.

While these data have not been fully written up and published, an abstract summarizing some of the results has been published (Thalmann et al, 1989 Jun). This is included as Appendix B. A few of the dives have been included in some general analyses; some are included in the "manifestations" report (Temple et al, 1999 May) and in volume VII of the series on statistically based decompression tables (Weathersby et al, 1992 Sep). These are found in Appendix C and Appendix D respectively.

#### 2. Description of the Project

These chamber dive simulations were conducted to determine the no-decompression dive times from 60 fsw for a variety of conditions: air-dry, air-wet, HeO<sub>2</sub>-dry, and HeO<sub>2</sub>-wet. The objectives were to compare these different conditions, and to see if the N<sub>2</sub>-O<sub>2</sub> no-stop limits can be extended.

An earlier objective was also to determine the effect of the immediate post-dive breathing gas after heliox dives. These dives were not carried out because the objectives were modified for project 88-06A.

Results of the initial dry dive series of 133 dives showed that the no-stop limits using air could be extended to 90-100 min, but that the time with HeO<sub>2</sub> was less, only 80 min, and this was much less than earlier NEDU reports suggested might be possible. The reason for this is unclear. One possibility is that skin absorption in the dry heliox dives may have played a more significant role than had been suspected. To test this a series of wet heliox dives were carried out, to see if preventing absorption of gas through the skin might be a factor. A series of wet air dives were done as well.

#### 3. Methods

Extracts from the original protocols are given in Appendix A. The types of dives conducted are given in the next section, A.4.

Dives were started with 10 min in lock on BIBS with bottom mix while lock atmosphere was switched to bottom mix. Lock depth was shallow, depth 10 fsw. Bottom time started on leaving this depth, descent exactly 1 min. Therefore time includes 1 min descent time.

Dry divers exercised on a bicycle ergometer at 125 watts for half of the bottom time, 10 min on exercise, 10 min off. Dive teams alternated on the bicycle. Wet divers exercised at 100 W to compensate for water resistance.

For wet dives, divers were compressed dry to dive depth minus 4 fsw, then descended in wet pot to bottom depth. Time at 56 fsw approximately 30 sec unless noted otherwise.

Water temp was 60 degrees F (15.6C). Divers wore wet suit farmer johns, jacket, booties, but no gloves. There was a 10 min stop at 10 fsw during descent, which was not included in the bottom time. Divers switched from air to bottom mix 3 min before descent from 10 fsw. Divers remained at chamber depth + 4 fsw in the wet pot until ascending to the surface. Divers ascended to surface of wet pot within 30 sec of the chamber reaching surface. Decompression was accomplished in a dry chamber at an ascent rate of 60 fsw/min directly to the surface.

Profiles were recorded in computer files; 1.5 fsw was added to each submerged depth in the computer files to bring the reference depth to mid-chest vice the top of the head.

Each diver should have had a detailed neurologic examination within 1 year and neuropsychologic baseline within 3 years, updated in the event of changes. The female diver was not pregnant.

External ear prophylaxis using a Otic Domboro solution was conducted a minimum of twice daily according to Navy practice. All prophylaxis was timed and logged.

DCS arising after dives was treated in accordance with Chapter 8 of the U. S. Navy Diving Manual. For subjects developing DCS, a neuropsychological assessment was performed to more completely evaluate the possibility that Type II DCS symptoms are present.

Other details are in protocol extracts in the appendix.

#### 4. Dive categories

Table 1. Summary of dive series

Series number	Protocol	Dive condition	Data file	Dive numbers	Number of man dives	# DCS	Bt range, min
A	80-86	Air, dry	NSW1A	A01-A12	60	1	70-100
B	80-86	Heliox, dry	NSW1B	B01-B16	79	14	70-120
C	80-86A	Air, wet	NSW1C	C01-C19	48	5	80-100
D	80-86A	Heliox, wet	NSW1D	D01-D29	75	4	70-120
E	80-86A	40% O <sub>2</sub> , wet	NSW1E	E01-E14	39	0	200-360
F	80-86A	40% O <sub>2</sub> , wet,	NSW1F	F01-F02	6	0	440
			Total number of dives		307	24	

Number of Man Dives is total number less number of divers that did not complete the dive.

## B. Diver list

A total of 38 diver-subjects participated in this project. In this report the divers names have been replaced with numbers. A "key" list of names and assigned diver numbers is on file with the original materials, presumably at the library of the Naval Medical Research Center, Forest Glen, MD. Cognizance of the list and materials rests with Ms. Diana Temple at NMRC. This key remains property of NMRC and can be made available to researchers who need it provided they will maintain diver anonymity throughout their analysis.

A list of diver numbers according to the dive exposure groups is given in Table 2, below. Diver ID numbers were assigned more or less randomly according to the diver list. If a diver did not complete a dive, due usually to ear clearing or equipment problems, the dive is not included in any of these lists or logs except the Thalmann log, which contains comments.

Table 2. Diver list

Diver Num	Air Dry NSW1A	Heliox dry NSW1B	Air wet NSW1C	Heliox wet NSW1D	40% long NSW1E	Mplx repet NSW1F
01	01, 05, 10, 11	05, 08, 12, 16	3, 9, 15, 17	2, 7, 11, 14, 18, 24, 28		
02	01, 05, 10		1, 6, 11, 16, 19			
03	01, 05	07, 11, 16	2, 10	5, 9, 15	3, 8	2
04	01, 05, 10	06, 08, 12, 16	1, 5, 17, 18	4, 11, 14, 20, 29	3, 8, 11	1
05	01, 05, 10, 12	04, 10, 16	2, 6, 14	8, 13, 18, 23	3, 8	1
06	02, 06					
07	02, 06	01, 11	19			
08	02, 06, 10, 12	05, 09, 14			4, 9, 12	
09	02, 06	01, 10				
10	02, 06, 11	02, 05, 08, 12, 15	7, 13	9, 19, 23	2	
11	03, 07, 12	01, 09, 13, 16				
12	03, 07	03, 07				
13	03, 07	07				
14	03, 07, 11	02, 05, 09, 12, 16		6, 10, 17, 21, 26	12	
15	03, 11	04	8, 10	7, 28	4, 13	
16	04, 08	02, 13	18	25	7	
17	04, 08	02, 11, 15	1, 5, 14	10, 15, 17, 21, 25	14	
18	04, 08, 11	01, 04, 14		1, 3, 13, 16, 27		
19	04, 08	02, 04, 06, 11, 13,	4, 9, 15	2, 8, 24		
20	04, 09, 12	08, 12, 14	3, 5, 11, 16	1, 5		
21	07	01, 03	2, 6, 12, 16	2	1, 4, 9	2
22	08	03, 11, 13, 15				
23	09	03, 15				
24	09	04, 06, 14	8, 13, 17	1, 3, 12, 19, 23, 28	1, 11	1
25	09	05				
26	09	03, 07, 10, 14	8, 12	12, 14, 19, 22, 29	1, 5	
27	12	08, 14				
28		06				
29		06, 10, 13	7, 12	6, 9, 16, 18, 24	2, 6, 10, 14	
30		09		25	5, 13	
31			3, 14	7, 10, 15, 20, 26		

Diver Num	Air Dry NSW1A	Heliox dry NSW1B	Air wet NSW1C	Heliox wet NSW1D	40% long NSW1E	Mplx repet NSW1F
32			18	4, 8		
33				22, 27	10, 14	
34				22, 27		2
35					2, 6, 9, 13	
36					6	
37					6, 7, 12	
38					10	

## C. Profiles and logs

Three types of profiles are included. The first type are extracts from the Conventional Log which is filled out by hand during the dive by the dive supervisor. In these we have listed the waypoints during each dive profile, showing the significant times, depths, and gas switches that affect decompression. These are grouped by dives, with or without decompression sickness. The second type of log is taken from Dr. Thalmann's notes. These list every man-dive as a line item. This log stresses the medical aspects of the dives. The third type is a printout of the available dives from the data base (not all dives were available to us).

### 1. Profiles Taken From Conventional Dive Log

These profiles are taken from the conventional Dive Log. Because there may be different ways of determining "bottom time" the profile shows several times. First the inclusive times are given, starting with L/S, Leave Surface, the beginning of pressurization. Next is the beginning of decompression, recorded here as L/B, Leave Bottom. The difference between these two times is the "classical" bottom time. This is recorded in the next column as "Bt (diff)". This is followed by the time difference as determined by the Dive Supervisor in writing the log summary, or by the difference in times if no sum is included in the log. Then the "Nominal" bottom time follows, the time used in data analysis. These last two may differ by a minute or two. Where seconds are shown, times are rounded.

The dry dives, A and B, include a stop for 10 min at 10 fsw during descent to permit gas switching. The time to 10 fsw is nominally 20 sec, and it usually is very close to that. The "classical" bottom time ("Bt(diff)") as given here includes the stop at 10 fsw as part of the dive, so to compare the times it is necessary to subtract 10 min from the Bt (diff) entry.

**Table 3. Dry air dives to 60 fsw. Dives A01 to A12.**

Date 1988	Dive num	L/S	L/B	Bt (diff)	Bt, log	Nom Bt	Num dvrs	Divers	# DCS	Comments
May09	A01	1107	1228	81	69	70	5	1, 2, 3, 4, 5	0	0:10 (10 min) at 10 fsw on descent
May10	A02	0934	1055	81	69	70	5	6, 7, 8, 9, 10	0	0:10 at 10 fsw on descent
May11	A03	0922	1053	91	79	80	5	11, 12, 13, 14, 15	0	0:10 at 10 fsw on descent
May12	A04	0912	1043	91	79	80	5	16, 17, 18, 19, 20	0	0:10 at 10 fsw on descent
May16	A05	0947	1127	100	89	90	5	1, 2, 3, 4, 5	0	0:10 at 10 fsw on descent. 2 divers, not identified, had itching.
May17	A06	0935	1116	101	89	90	5	6, 7, 8, 9, 10	0	0:10 at 10 fsw on descent

Date 1988	Dive num	L/S	L/B	Bt (diff)	Bt, log	Nom Bt	Num dvrs	Divers	# DCS	Comments
May18	A07	0903	1054	111	99	100	5	11, 12, 13, 14, 21	1	0:10 at 10 fsw on descent. Diver 13 treated for DCS after surfacing, tt6.
May19	A08	0920	1111	111	99	100	5	16, 17, 18, 19, 22	0	0:10 at 10 fsw on descent
May20	A09	0843	1034	111	101	100	5	20, 23, 24, 25, 26	0	0:10 at 10 fsw on descent
May23	A10	0947	1138	111	101	100	5	1, 2, 4, 5, 8	0	0:10 at 10 fsw on descent
Jun13	A11	1057	1238	101	89	90	5	1, 10, 14, 15, 18	0	0:10 at 10 fsw on descent
Jun14	A12	0911	1052	101	89	90	5	5, 8, 11, 20, 27	0	0:10 at 10 fsw on descent
				Total man dives			60	Num DCS cases	1	

Explanation of columns from left to right:

**Date, 1988.** Date of dive

**Dive num.** Dive number. Dive number assigned by data collection protocol.

**L/S.** Leave Surface; beginning of classical bottom time, time of day.

**L/B.** Leave Bottom; end of classical bottom time, time of day.

**Bt (diff).** Differential bottom time, the time between L/S and L/B, in minutes. As shown here these normally include the 10 min stop at 10 fsw in the dry dives, which is normally ignored in determining the useable bottom time. Bt may be written as B time.

**Bt, log.** Elapsed time from log, l/s to l/b, using the times recorded in the end-of-dive summary in the log.

**Nom Bt.** "Nominal" bottom time, the time used for identifying and grouping the dives during data analysis.

**Num dvrs.** The number of divers in this dive.

**Divers.** Diver numbers (from the diver ID list).

**# DCS.** Number of divers having decompression sickness (not including niggles and itching). This is not the type of DCS, only the number of cases on this dive. These are usually not taken from the Conventional Log. For details of DCS see Thalmann logs and medical reports.

**Comments.** Any unusual happenings or deviations from protocol. Shows dives where the 10 fsw/10 min stop is included in the time shown in the BT (diff) column.

For dives less than 100 min the divers each completed three 10-min sessions of exercise on a bicycle ergometer set for 125 watts. For the 100 min dives they did 4 cycles. There was at least one full rest period before decompression.

The data file that presumably contains the profiles of this dive set is NSW1A. This file was not available to us and is not included with this report.

**Table 4. Dry Heliox dives to 60 fsw, dives B01-B16.**

Date 1988	Dive num	L/S	L/B	Bt (diff)	Bt, log	Nom Bt	Num dvrs	Divers	# DCS	Comments
May 24	B01	0911	1121	130	119	120	5	7, 9, 11, 18, 21	3	0:10 at 10 fsw descending
May25	B02	1025	1216	111	110	100	5	10, 14, 16, 17, 19	0	0:10 at 10 fsw descending
Jun01	B03	0927	1117	110	110	100	5	12, 21, 22, 23, 26	1	0:10 at 10 fsw descending
Jun02	B04	0740	0931	111	112	100	5	5, 15, 18, 19, 24	1	0:10 at 10 fsw descending
Jun02	B05	1042	1233	111	112	100	5	1, 8, 10, 14, 25	3	0:12 at 10 fsw descending



Date 1988	Dive num	L/S	L/B	Bt (diff)	Bt, log	Nom Bt	Num dvrs	Divers	# DCS	Comments
Jun15	B06	0919	1040	81	69	70	5	4, 19, 24, 28, 29	0	0:10 at 10 fsw descending
Jun16	B07	0843	1003	80	69	70	4	3, 12, 13, 26	2	0:10 at 10 fsw descending
Jun21	B08	0906	1027	81	81	70	5	1, 4, 10, 20, 27	0	0:10 at 10 fsw descending
Jun22	B09	0905	1025	80	80	70	4	8, 11, 14, 30	0	0:10 at 10 fsw descending
Jun22	B10	1135	1307	92	92	80	4	5, 9, 26, 29	0	0:10 at 10 fsw descending
Jun23	B11	0949	1120	91	91	80	5	3, 7, 17, 19, 22	0	0:10 at 10 fsw descending
Jun30	B12	1002	1142	100	91	90	5	1, 4, 10, 14, 20	2	0:10 at 10 fsw descending
Jun30	B13	1247	1427	100	91	90	5	11, 16, 19, 22, 29	1	0:10 at 10 fsw descending
Jul06	B14	0837	1011	94	82	80	6	8, 18, 20, 24, 26, 27	1	0:10 at 10 fsw descending
Jul06	B15	1323	1453	90	90	80	5	10, 17, 19, 22, 23	0	0:10 at 10 fsw descending
Jul07	B16	0837	1008	91	91	80	6	1, 3, 4, 5, 11, 14	0	0:10 at 10 fsw descending
Total man-dives							79	Total DCS cases	14	

Note that conventional logs are not consistent as to whether the 10 min at 10 fsw is included in bottom time or not. It is not included in the "nominal" time.

The data file that presumably contains the profiles of this dive set is NSW1B. This file was not available to us and is not included with this report.

**Table 5. Wet air dives to 60 fsw, dives C01-C19.**

These dives are in Data Set NSW1C, found in file NMRNSW2

Date 1988	Dive num	L/S	L/B	Bt (diff)	Bt Log	Nom Btime	Num dvrs	Divers	# DCS	Comments
19Sep	C01	1032	1155	83	83	80	3	2, 4, 17	0	
20Sep	C02	0930	1054	84	84	80	3	3, 5, 21	0	2 min hold on descent
20Sep	C 03	1306	1428	82	84	80	3	1, 20, 31	0	
22Sep	C04	1001	1133	92	90	90	1	19	0	#22 & 24 aborted dive
26Sep	C05	1118	1250	92	92	90	3	4, 17, 20	0	
27Sep	C06	0918	1050	92	93	90	3	2, 5, 21	1	#5 pain in shoulder, tt5, ok
27Sep	C07	1304	1437	93	92	90	2	10, 29	0	
28 Sep	C08	0922	1054	92	94	90	3	15, 24, 26	0	
29Sep	C09	0927	1059	92	93	90	2	1, 19	0	
03Oct	C10	0818	0951	93	94	90	2	3, 15	0	
03Oct	C11	1201	1333	92	93	90	2	2, 20	0	
04Oct	C12	0916	1059	103	103	100	3	21, 26, 29	0	Dive recorded as 90 min in Table 11

Date 1988	Dive num	L/S	L/B	Bt (diff)	Bt Log	Nom Btime	Num dvrs	Divers	# DCS	Comments
04Oct	C13	1314	1457	103	100	100	2	10, 24	0	
05Oct	C14	1122	1308	106	106	100	3	5, 17, 31	1	
06Oct	C15	0946	1129	103	100	100	2	1, 19	0	
11Oct	C16	1048	1230	102	102	100	3	2, 20, 21	1	
12Oct	C17	1252	1425	93	93	90	3	1, 4, 24	1	
19Oct	C18	0923	1048	85	85	80	3	4, 16, 32	0	
20Oct	C19	1145	1307	82	82	80	2	2, 7	1	
				Total man-dives			48	DCS cases	5	

Note: Dive C12 is recorded as 90 min in Table 11.

**Table 6. Wet Heliox dives to 60 fsw, dives D01-D29.**

Date 1988	Dive num	Start time	End time	Bt (diff)	Log Btime	Nom Btime	Num divers	Divers	DCS	Comments
18Oct	D01	0944	1056	72	72	70	3	18, 20, 24	0	
24Oct	D02	1023	1136	73	72	70	3	1, 19, 21	1	
27Oct	D03	0915	1028	73	73	70	2	18, 24	0	
28Oct	D04	0929	1044	75	75	70	2	4, 32	0	
31Oct	D05	1009	1121	72	72	70	2	3, 20	0	
01Nov	D06	0942	1054	72	72	70	3	10, 14, 29	0	Log: 10&29 work 3x, 14 works 2x
02Nov	D07	1008	1122	74	74	70	3	1, 15, 31	0	
03Nov	D08	0933	1055	82	82	80	3	5, 19, 32	0	
07Nov	D09	1033	1155	82	82	80	3	3, 10, 29	0	
08Nov	D10	0933	1055	82	82	80	3	14, 17, 31	0	
09Nov	D11	1004	1137	93	94	90	2	1, 4	0	
09Nov	D12	1350	1522	92	92	90	2	24, 26	0	
10Nov	D13	0919	1051	92	90	90	2	5, 18	0	
15Nov	D14	0907	1039	92	92	90	3	1, 4, 26	0	
15Nov	D15	1257	1430	93	93	90	3	3, 17, 31	0	
16Nov	D16	0813	0949	96	96	90	3	18, 29	0	Compression delayed 3 min
30Nov	D17	0953	1125	92	92	90	2	14, 17	0	
01Dec	D18	0908	1050	102	102	100	3	1, 5, 29	0	
01Dec	D19	1303	1445	102	102	100	3	10, 24, 26	0	

Date 1988	Dive num	Start time	End time	Bt (diff)	Log Btime	Nom Btime	Num divers	Divers	DCS	Comments
05Dec	D20	1012	1154	102	100	100	2	4, 31	0	
06Dec	D21	0917	1059	102	102	100	2	14, 17	0	
07Dec	D22	0927	1121	114	110	110	3	26, 33, 34	0	
08Dec	D23	0932	1124	112	110	110	3	5, 10, 24	0	
08Dec	D24	1331	1525	114	114	110	3	1, 19, 29	0	
12Dec	D25	1044	1248	124	124	120	3	16, 17, 24	0	
12Dec	D26	1428	1630	122	122	120	2	14, 31	1	
13Dec	D27	1008	1211	123	120	120	3	18, 33, 34	0	
14Dec	D28	0931	1134	123	123	120	2	1, 24	2	#15 helmet flooded, aborted
14Dec	D29	1259	1501	122	122	120	2	4, 26	0	
				Total man-dives			75	# DCS cases	4	

The data file that presumably contains the profiles of this dive set is NSW1D. This file was not available to us and is not included with this report.

**Table 7. 40% oxygen dives to 60 fsw, dives E01-E14.**

These dives are in Data Set NSW1D, found in file NMRNSW2

Date 1989	Dive num	Start time	End time	Bt (diff)	Log B time	Nom B time	Num divers	Divers	DCS	Comments
04Jan	E01	1001	1403	242	240	240	3	21, 24, 26	0	
05Jan	E02	0944	1347	243	243	240	3	10, 29, 35	0	
06Jan	E03	0923	1326	243	240	240	3	3, 4, 5	0	
09Jan	E04	0859	1401	302	302	300	3	8, 15, 21	0	
10Jan	E05	0820	1322	302	304	300	2	26, 30	0	#24 left dive at 2 hr, helmet prob.
11Jan	E06	0826	1330	304	304	300	3	29, 35, 36	0	
12Jan	E07	1053	1556	303	304	300	2	16, 37	0	
13Jan	E08	0802	1405	363	363	360	3	3, 4, 5	0	
17Jan	E09	0804	1407	363	363	360	3	8, 21, 35	0	
18Jan	E10	0731	1334	363	363	360	3	29, 33, 38	0	
19Jan	E11	0733	1338	365	365	360	2	4, 24	0	
23Jan	E12	0838	1440	362	363	360	3	8, 14, 37	0	
24Jan	E13	0757	1359	362	362	360	3	15, 30, 35	0	
27Jan	E14	0723	1327	364	364	360	3	17, 29, 33	0	
				Total man-dives			39	#DCS cases	0	

The following two tables, Tables 8a and 8b, contain detailed extracts of times, depths, and gas switches taken from the Conventional Log for dives F01 and F02. These were wet, no-stop dives with a multiple repetitive pattern to 60 fsw, divers breathing 40% O<sub>2</sub>. As for other wet dives, the divers were 4 feet below the surface and 1.5 fsw were added to the data base values to account for the difference between the top of the diver's head and the chest.

**Table 8a. Multiple repetitive dives to 60 fsw using 40% O<sub>2</sub>-N<sub>2</sub>, Dive F01.**

Start time	Clock time	Run time, min	Depth, fsw	Gas mix	Event
0738	0738	0	0	40%O <sub>2</sub> -N <sub>2</sub>	On gas
0738	0741	3	0		L/S
0738	0744	6	56 [61.5]		R/B
0738	0914::21	96			L/B
0738	0915::44	97	0		R/S
0738	0917::14	99	0	air	Off gas
0738	0932	114	0	40%O <sub>2</sub> -N <sub>2</sub>	On gas
0738	0934::18	116	0		L/S
0738	0937::21	119	56 [61.5]		R/B
0738	1107::38	209			L/B
0738	1110	212	0		
0738	1110::34	212	0	air	Off gas
0738	1116	218	0		Divers drinking
0738	1125::36	227	0	40%O <sub>2</sub> -N <sub>2</sub>	On gas
0738	1127::37	229	0		L/S
0738	1130::34	232	56 [61.5]		R/B
0738	1300::39	322			L/B
0738	1302::01	324	0		R/S
0738	1303::34	325	0	air	Off gas
0738	1319	341	0	40%O <sub>2</sub> -N <sub>2</sub>	On gas
0738	1320::40	342	0		L/S
0738	1323::41	345	56 [61.5]		R/B
0738	1454	436			L/B
0738	1455::29	437	0		R/S
0738	1456::18	438	0	air	Off gas

Data file NSW1F01 Divers 4, 24, 5. No DCS.

**Table 8b. Multiple repetitive dives to 60 fsw using 40% O<sub>2</sub>-N<sub>2</sub>, Dive F02.**

Start time	Clock time	Run time, min	Depth, fsw	Gas mix	Event
0740	0740	0	0	40%O <sub>2</sub> -N <sub>2</sub>	On gas
0740	0744	4	0		L/S
0740	0748	8	56 [61.5]		R/B
0740	0917	97			L/B
0740	0918	98	0		R/S
0740	0920	100	0	air	Off Gas

Start time	Clock time	Run time, min	Depth, fsw	Gas mix	Event
0740	0932	112	0		Divers taking fluids
0740	0936	116	0	40%O <sub>2</sub> -N <sub>2</sub>	[On gas]
0740	0940	120	56 [61.5]		R/B
0740	1110	210			L/B
0740	1112	212	0		R/S
0740	1113	213	0	air	Off gas
0740	1126	226	0		Divers taking fluids
0740	1128	228	0	40%O <sub>2</sub> -N <sub>2</sub>	On gas
0740	1130	230	0		L/S
0740	1133	233	56 [61.5]		R/B
0740	1304	324			L/B
0740	1305	325	0		R/S
0740	1307	327	0	air	Off gas
0740	1315	335			Divers taking fluids
0740	1322	342	0	40%O <sub>2</sub> -N <sub>2</sub>	On gas
0740	1324	344	0		L/S
0740	1327	347	56 [61.5]		R/B
0740	1457	437			L/B
0740	1458	438	0		R/S
0740	1459	439	0	air	Off gas

Data file NSW1F02. Divers 21, 34, 3. No DCS.

Small pressure differences, such as the 4 fsw for the time between the chamber reaching surface and the divers leaving the water are rounded and/or not shown.

Run Time is the difference between Clock Time and Starting Time. Formula used for this is:

$$+INT(B2/100)*60+(B2-(INT(B2/100)*100))-(INT(A2/100)*60+(A2-(INT(A2/100)*100)))$$

## 2. Profile Information from Notes by Dr. Thalmann

An additional set of log information has been taken from the logbook of Dr. Thalmann. These are listed for each individual diver. Decompression sickness is scored as follow. Niggles are not considered to be DCS in this analysis.

0 = no symptom

N = niggles

1 = limb bends, pain only

2 = neurological dcs

Note that there are some differences between the results as indicated in these logs and the results reported in the protocol for 88-06A and the published abstract (both in the appendix).

**Table 9. Dry air dives to 60 fsw. Dives A01 to A12.**

Data file NSW1A (not available with this report).

Date	File	Depth	Btime	Gas	Wet/dry	Work	DCS	Diver#	Notes
88May09	nsw1a01	60	70	air	dry	125W	0	5	
88May09	nsw1a01	60	70	air	dry	125W	0	2	
88May09	nsw1a01	60	70	air	dry	125W	0	1	
88May09	nsw1a01	60	70	air	dry	125W	0	3	
88May09	nsw1a01	60	70	air	dry	125W	0	4	
88May10	nsw1a02	60	70	air	dry	125W	0	8	
88May10	nsw1a02	60	70	air	dry	125W	0	6	
88May10	nsw1a02	60	70	air	dry	125W	0	10	
88May10	nsw1a02	60	70	air	dry	125W	0	7	
88May10	nsw1a02	60	70	air	dry	125W	0	9	
88May11	nsw1A03	60	70	air	dry	125W	0	15	
88May11	nsw1A03	60	70	air	dry	125W	0	11	
88May11	nsw1A03	60	70	air	dry	125W	0	13	
88May11	nsw1A03	60	70	air	dry	125W	0	12	
88May11	nsw1A03	60	70	air	dry	125W	0	14	
88May12	nsw1A04	60	80	air	dry	125W	0	17	
88May12	nsw1A04	60	80	air	dry	125W	0	20	
88May12	nsw1A04	60	80	air	dry	125W	0	16	
88May12	nsw1A04	60	80	air	dry	125W	0	18	
88May12	nsw1A04	60	80	air	dry	125W	0	19	
88May16	nsw1A05	60	90	air	dry	125W	0	5	
88May16	nsw1A05	60	90	air	dry	125W	0	2	
88May16	nsw1A05	60	90	air	dry	125W	0	1	
88May16	nsw1A05	60	90	air	dry	125W	0	3	
88May16	nsw1A05	60	90	air	dry	125W	0	4	
88May17	nsw1A06	60	90	air	dry	125W	0	8	
88May17	nsw1A06	60	90	air	dry	125W	0	10	
88May17	nsw1A06	60	90	air	dry	125W	0	7	
88May17	nsw1A06	60	90	air	dry	125W	0	9	
88May17	nsw1A06	60	90	air	dry	125W	n	6	#1
88May18	nsw1A07	60	100	air	dry	125W	0	11	#2
88May18	nsw1A07	60	100	air	dry	125W	0	12	#2
88May18	nsw1A07	60	100	air	dry	125W	0	21	#2
88May18	nsw1A07	60	100	air	dry	125W	0	14	#2
88May18	nsw1A07	60	100	air	dry	125W	2	13	#3
88May19	nsw1A08	60	100	air	dry	125W	0	22	
88May19	nsw1A08	60	100	air	dry	125W	0	17	
88May19	nsw1A08	60	100	air	dry	125W	0	16	
88May19	nsw1A08	60	100	air	dry	125W	0	18	
88May19	nsw1A08	60	100	air	dry	125W	0	19	
88May20	nsw1A09	60	100	air	dry	125W	0	20	
88May20	nsw1A09	60	100	air	dry	125W	0	24	
88May20	nsw1A09	60	100	air	dry	125W	0	23	
88May20	nsw1A09	60	100	air	dry	125W	0	25	
88May20	nsw1A09	60	100	air	dry	125W	0	26	
88May23	nsw1A10	60	100	air	dry	125W	0	8	
88May23	nsw1A10	60	100	air	dry	125W	0	5	
88May23	nsw1A10	60	100	air	dry	125W	0	2	

88May23	nsw1A10	60	100	air	dry	125W	0	1
88May23	nsw1A10	60	100	air	dry	125W	0	4
88Jun13	nsw1A11	60	90	air	dry	125W	0	15
88Jun13	nsw1A11	60	90	air	dry	125W	0	10
88Jun13	nsw1A11	60	90	air	dry	125W	0	18
88Jun13	nsw1A11	60	90	air	dry	125W	0	1
88Jun13	nsw1A11	60	90	air	dry	125W	0	14
88Jun14	nsw1A12	60	90	air	dry	125W	0	8
88Jun14	nsw1A12	60	90	air	dry	125W	0	5
88Jun14	nsw1A12	60	90	air	dry	125W	0	27
88Jun14	nsw1A12	60	90	air	dry	125W	0	20
88Jun14	nsw1A12	60	90	air	dry	125W	0	11

#1 Transient rt Knee pain, resolved 5min post sfc

#2 Post-dive itching, transient

#3 Post-dive itching, transient. Bilateral leg hyperesthesia, tt6, ok. No medical report available for this treatment.

**Table 10. Dry Heliox dives to 60 fsw, B01-B16.**

Data file NSW1B (not available with this report).

Date	File	Depth	Btime	Gas	Wet/dry	Work	DCS	Diver#	notes
88May24	nsw1B01	60	120	HeO <sub>2</sub> (21%)	dry	125W	0	18	
88May24	nsw1B01	60	120	HeO <sub>2</sub> (21%)	dry	125W	0	7	
88May24	nsw1B01	60	120	HeO <sub>2</sub> (21%)	dry	125W	1	11	#1
88May24	nsw1B01	60	120	HeO <sub>2</sub> (21%)	dry	125W	1	21	#2
88May24	nsw1B01	60	120	HeO <sub>2</sub> (21%)	dry	125W	1	9	
88May25	nsw1B02	60	120#3	HeO <sub>2</sub> (21%)	dry	125W	0	17	
88May25	nsw1B02	60	120#3	HeO <sub>2</sub> (21%)	dry	125W	0	16	
88May25	nsw1B02	60	120#3	HeO <sub>2</sub> (21%)	dry	125W	0	10	
88May25	nsw1B02	60	120#3	HeO <sub>2</sub> (21%)	dry	125W	0	19	
88May25	nsw1B02	60	120#3	HeO <sub>2</sub> (21%)	dry	125W	0	14	
88Jun01	nsw1B03	60	100	HeO <sub>2</sub> (21%)	dry	125W	0	22	
88Jun01	nsw1B03	60	100	HeO <sub>2</sub> (21%)	dry	125W	0	23	
88Jun01	nsw1B03	60	100	HeO <sub>2</sub> (21%)	dry	125W	0	12	
88Jun01	nsw1B03	60	100	HeO <sub>2</sub> (21%)	dry	125W	0	26	
88Jun01	nsw1B03	60	100	HeO <sub>2</sub> (21%)	dry	125W	1	21	#4
88Jun02	nsw1B04	60	100	HeO <sub>2</sub> (21%)	dry	125W	0	5	
88Jun02	nsw1B04	60	100	HeO <sub>2</sub> (21%)	dry	125W	0	24	
88Jun02	nsw1B04	60	100	HeO <sub>2</sub> (21%)	dry	125W	0	15	
88Jun02	nsw1B04	60	100	HeO <sub>2</sub> (21%)	dry	125W	0	18	
88Jun04	nsw1B04	60	100	HeO <sub>2</sub> (21%)	dry	125W	1	19	#5
88Jun02	nsw1B05	60	100	HeO <sub>2</sub> (21%)	dry	125W	0	8	
88Jun02	nsw1B05	60	100	HeO <sub>2</sub> (21%)	dry	125W	0	10	
88Jun02	nsw1B05	60	100	HeO <sub>2</sub> (21%)	dry	125W	1	1	#6
88Jun02	nsw1B05	60	100	HeO <sub>2</sub> (21%)	dry	125W	1	25	#6
88Jun02	nsw1B05	60	100	HeO <sub>2</sub> (21%)	dry	125W	1	14	#6
88Jun15	nsw1B06	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	29	
88Jun15	nsw1B06	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	24	
88Jun15	nsw1B06	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	28	
88Jun15	nsw1B06	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	19	
88Jun15	nsw1B06	60	70	HeO <sub>2</sub> (21%)	dry	125W	n	4	#7



88Jun16	nsw1B07	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	3	
88Jun16	nsw1B07	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	26	
88Jun16	nsw1B07	60	70	HeO <sub>2</sub> (21%)	dry	125W	2	13	#8
88Jun16	nsw1B07	60	70	HeO <sub>2</sub> (21%)	dry	125W	2	12	#9
88Jun21	nsw1B08	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	27	
88Jun21	nsw1B08	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	24	
88Jun21	nsw1B08	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	10	
88Jun21	nsw1B08	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	1	
88Jun21	nsw1B08	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	4	
88Jun22	nsw1B09	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	8	
88Jun22	nsw1B09	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	11	
88Jun22	nsw1B09	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	30	
88Jun22	nsw1B09	60	70	HeO <sub>2</sub> (21%)	dry	125W	0	14	
88Jun22	nsw1B10	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	29	#10
88Jun22	nsw1B10	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	5	#10
88Jun22	nsw1B10	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	26	#10
88Jun22	nsw1B10	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	9	#10
88Jun23	nsw1B11	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	22	
88Jun23	nsw1B11	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	17	
88Jun23	nsw1B11	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	3	
88Jun23	nsw1B11	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	7	
88Jun23	nsw1B11	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	26	
88Jun30	nsw1B12	60	90	HeO <sub>2</sub> (21%)	dry	125W	0	20	
88Jun30	nsw1B12	60	90	HeO <sub>2</sub> (21%)	dry	125W	0	10	
88Jun30	nsw1B12	60	90	HeO <sub>2</sub> (21%)	dry	125W	0	4	
88Jun30	nsw1B12	60	90	HeO <sub>2</sub> (21%)	dry	125W	1	1	#19
88Jun30	nsw1B12	60	90	HeO <sub>2</sub> (21%)	dry	125W	1	14	#19
88Jun30	nsw1B13	60	90	HeO <sub>2</sub> (21%)	dry	125W	0	22	
88Jun30	nsw1B13	60	90	HeO <sub>2</sub> (21%)	dry	125W	0	11	
88Jun30	nsw1B13	60	90	HeO <sub>2</sub> (21%)	dry	125W	0	16	
88Jun30	nsw1B13	60	90	HeO <sub>2</sub> (21%)	dry	125W	0	19	
88Jun30	nsw1B13	60	90	HeO <sub>2</sub> (21%)	dry	125W	1	29	#11
88Jul06	nsw1B14	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	20	#14
88Jul06	nsw1B14	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	24	#14
88Jul06	nsw1B14	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	18	#14
88Jul06	nsw1B14	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	26	#12, #14
88Jul06	nsw1B14	60	80	HeO <sub>2</sub> (21%)	dry	125W	1	27	#13, #14
88Jul06	nsw1B14	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	8	#14
88Jul06	nsw1B15	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	17	
88Jul06	nsw1B15	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	23	
88Jul06	nsw1B15	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	10	
88Jul06	nsw1B15	60	80	HeO <sub>2</sub> (21%)	dry	125W	n	22	#15
88Jul06	nsw1B15	60	80	HeO <sub>2</sub> (21%)	dry	125W	n	19	#16
88Jul07	nsw1B16	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	5	#17
88Jul07	nsw1B16	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	11	#18
88Jul07	nsw1B16	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	1	#17
88Jul07	nsw1B16	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	3	#18
88Jul07	nsw1B16	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	4	#18
88Jul07	nsw1B16	60	80	HeO <sub>2</sub> (21%)	dry	125W	0	14	#18

#1 Previous DCS, May 19.

#2 Previous DCS rt elbow, 87 Nov.

#3 This was a 100 min dive if the time at 10 fsw is not included. Other logs say 100 min.



- #4 Rt elbow ache 35 min post sfc, tt5, complete relief.
- #5 Rt elbow pain 4 hr post sfc, tt5, 20 hr post dive, complete relief; date of dive 88Jun02.
- #6 See medical report.
- #7 Transient discomfort triceps insertion 30 min Postdive, resolved by 2 hr.
- #8 Abnormal fatigue, 2-4 hr postdive, transient tingling left face, rt foot, 2-4 hr postdive. Neuro normal before tmt, tt6.
- #9 Disesthesias rt arm 30 min postdive, decreased sharp-dull discrimination rt forearm 2 hr postdive. Tt6, resolved.
- #10 1 min hold 29 fsw for squeeze (Diver 9).
- #11 Hip pain tt5, complete relief.
- #12 Transient post-dive itching.
- #13 Rt elbow pain 12 min postdive, tt5, complete relief.
- #14 3 mi hold at 6.7 fsw, 4 min hold 10 fsw, 2 min descent 10 to 60 fsw (all divers in B14)
- #15 Transient leg niggles during night.
- #16 Transient hip and elbow niggles during night.
- #17 Completed 3 work cycles on schedule.
- #18 Completed only 2 work cycles.
- #19 No medical report available.

Table 11. Wet air dives to 60 fsw, C01-C19.  
Data file NSW1C. Found in NMRNSW2.

Date	File	Depth	Time	Gas	Wet/dry	Work	DCS	Diver#	notes
88Sep19	nsw1C01	60	80	Air	wet 60F	125W	0	17	
88Sep19	nsw1C01	60	80	Air	wet 60F	125W	0	2	
88Sep19	nsw1C01	60	80	Air	wet 60F	125W	0	4	
88Sep20	nsw1C02	60	80	Air	wet 56F	125W	0	5	#1
88Sep20	nsw1C02	60	80	Air	wet 56F	125W	0	21	
88Sep20	nsw1C02	60	80	Air	wet 56F	125W	0	3	
88Sep20	nsw1C03	60	80	Air	wet 59F	100W	0	1	#2
88Sep20	nsw1C03	60	80	Air	wet 59F	100W	0	31	
88Sep20	nsw1C03	60	80	Air	wet 59F	100W	n	20	#3
88Sep22	nsw1C04	60	90	Air	wet 60F	100W	0	22	#4
88Sep22	nsw1C04	60	90	Air	wet 60F	100W	0	24	#5
88Sep22	nsw1C04	60	90	Air	wet 60F	100W	0	19	#6
88Sep26	nsw1C05	60	90	Air	wet 63F	100W	0	17	
88Sep26	nsw1C05	60	90	Air	wet 63F	100W	0	20	
88Sep26	nsw1C05	60	90	Air	wet 63F	100W	0	4	
88Sep27	nsw1C06	60	90	Air	wet 59F	100W	0	2	
88Sep27	nsw1C06	60	90	Air	wet 59F	100W	0	21	
88Sep27	nsw1C06	60	90	Air	wet 59F	100W	1	5	#7
88Sep27	nsw1C07	60	90	Air	wet 59F	100W	0	29	
88Sep27	nsw1C07	60	90	Air	wet 59F	100W	0	10	
88Sep28	nsw1C08	60	90	Air	wet 59F	100W	0	24	
88Sep28	nsw1C08	60	90	Air	wet 59F	100W	0	15	
88Sep28	nsw1C08	60	90	Air	wet 59F	100W	0	26	
88Sep29	nsw1C09	60	90	Air	wet 63F	100W	0	1	
88Sep29	nsw1C09	60	90	Air	wet 63F	100W	0	19	
88Oct03	nsw1C10	60	90	Air	wet 59F	100W	0	15	
88Oct03	nsw1C10	60	90	Air	wet 59F	100W	0	3	
88Oct03	nsw1C11	60	90	Air	wet 59F	100W	0	20	
88Oct03	nsw1C11	60	90	Air	wet 59F	100W	0	2	

88Oct04	nsw1C12	60	90#14	Air	wet 59F	100W	0	29	#8, #14
88Oct04	nsw1C12	60	90#14	Air	wet 59F	100W	0	21	#14
88Oct04	nsw1C12	60	90#14	Air	wet 59F	100W	0	26	#14
88Oct04	nsw1C13	60	100	Air	wet 59F	100W	0	24	#9
88Oct04	nsw1C13	60	100	Air	wet 59F	100W	0	10	
88Oct05	nsw1C14	60	100	Air	wet 60F	100W	0	17	
88Oct05	nsw1C14	60	100	Air	wet 60F	100W	0	31	
88Oct05	nsw1C14	60	100	Air	wet 60F	100W	2	5	#10
88Oct06	nsw1C15	60	100	Air	wet 60F	100W	0	1	
88Oct06	nsw1C15	60	100	Air	wet 60F	100W	0	19	
88Oct11	nsw1C16	60	100	Air	wet 60F	100W	0	20	
88Oct11	nsw1C16	60	100	Air	wet 60F	100W	0	21	
88Oct11	nsw1C16	60	100	Air	wet 60F	100W	1	2	#11
88Oct12	nsw1C17	60	90	Air	wet 60F	100W	0	24	
88Oct12	nsw1C17	60	90	Air	wet 60F	100W	0	1	
88Oct12	nsw1C17	60	90	Air	wet 60F	100W	1	4	#12
88Oct19	nsw1C18	60	80	Air	wet 60F	100W	0	16	
88Oct19	nsw1C18	60	80	Air	wet 60F	100W	0	32	
88Oct19	nsw1C18	60	80	Air	wet 60F	100W	0	4	
88Oct20	nsw1C19	60	80	Air	wet 60F	100W	0	7	
88Oct20	nsw1C19	60	80	Air	wet 60F	100W	2	2	#13

- #1 2 min hold at 40 fsw during descent, all divers nsw1co2
- #2 Pstdive fatigue
- #3 Transient shoulder niggles 3 hr postdive
- #4 Ear squeeze, removed from dive at 35 fsw during descent.
- #5 4 min descent to 35 fsw, 4 min ascent back to sfc, dive restarted 7 min post surface. Suit squeeze 60 fsw, 27 min into dive, left dive.
- #6 4 min descent to 35 fsw, 4 min ascent back to sfc, dive restarted 7 min post surface.
- #7 Right bicep ache 2 hr post dive, remained steady for next 2 hr, tt5, complete relief.
- #8 14 min after reaching 60 fsw ascended to 56 fsw to change UBA in dry chamber. Transient itching 3 to 3.5 hr postdive.
- #9 Transient itching 3 to 45 min postdive
- #10 Numbness, rt arm and rt wrist, 2 min postdive, progressed over next 10 min. Fatigue and rash over rt pectoral area. TT6 2 hr postdive, complete relief.
- #11 Knee ache 6 hr postdive, increased to severe pain over next hour, affected gait. Recompressed 3.5 hr postdive, complete relief.
- #12 Rt knee pain 8.5 hr postdive, tt5, complete relief.
- #13 Rapid onset 35 min postdive; see medical report.
- #14 Conventional Log and the data base say this dive was for 100 min.

Note: Two divers #22 and #24 did not complete this dive; see notes #4 and #5

**Table 12. Wet Heliox dives to 60 fsw, D01-D29.**

Data file NSW1D (not available with this report).

Date	File	Depth	Btime	Gas	Wet/dry	Work	DCS	Diver	#Notes
88Oct18	nsw1D01	60	70	HeO2(21%)	wet 60F	100W	0	20	
88Oct18	nsw1D01	60	70	HeO2(21%)	wet 60F	100W	0	24	
88Oct18	nsw1D01	60	70	HeO2(21%)	wet 60F	100W	0	18	
88Oct24	nsw1D02	60	70	Air #9	wet 60F	100W	0	1	
88Oct24	nsw1D02	60	70	Air #9	wet 60F	100W	0	19	

88Oct24	nsw1D02	60	70	Air #9	wet 60F	100W	1	21	#1
88Oct25	nsw1D03	60	70	HeO2(21%)	wet 60F	100W	0	24	
88Oct25	nsw1D03	60	70	HeO2(21%)	wet 60F	100W	0	18	
88Oct26	nsw1D04	60	70	HeO2(21%)	wet 60F	100W	n	32	#2
88Oct26	nsw1D04	60	70	HeO2(21%)	wet 60F	100W	n	4	#3
88Oct26	nsw1D05	60	70	HeO2(21%)	wet 60F	100W	0	20	
88Oct26	nsw1D05	60	70	HeO2(21%)	wet 60F	100W	0	3	
88Nov01	nsw1D06	60	70	HeO2(21%)	wet 60F	100W	0	29	
88Nov01	nsw1D06	60	70	HeO2(21%)	wet 60F	100W	0	10	
88Nov01	nsw1D06	60	70	HeO2(21%)	wet 60F	100W	0	14	
88Nov02	nsw1D07	60	70	HeO2(21%)	wet 60F	100W	0	15	
88Nov02	nsw1D07	60	70	HeO2(21%)	wet 60F	100W	0	1	
88Nov02	nsw1D07	60	70	HeO2(21%)	wet 60F	100W	0	31	
88Nov03	nsw1D08	60	80	HeO2(21%)	wet 60F	100W	0	5	
88Nov03	nsw1D08	60	80	HeO2(21%)	wet 60F	100W	0	32	
88Nov03	nsw1D08	60	80	HeO2(21%)	wet 60F	100W	0	19	
88Nov07	nsw1D09	60	80	HeO2(21%)	wet 60F	100W	0	29	
88Nov07	nsw1D09	60	80	HeO2(21%)	wet 60F	100W	0	10	
88Nov07	nsw1D09	60	80	HeO2(21%)	wet 60F	100W	0	3	
88Nov08	nsw1D10	60	80	HeO2(21%)	wet 60F	100W	0	17	
88Nov08	nsw1D10	60	80	HeO2(21%)	wet 60F	100W	0	31	
88Nov08	nsw1D10	60	80	HeO2(21%)	wet 60F	100W	0	14	
88Nov09	nsw1D11	60	90	HeO2(21%)	wet 60F	100W	0	1	#4
88Nov09	nsw1D11	60	90	HeO2(21%)	wet 60F	100W	0	4	
88Nov09	nsw1D12	60	90	HeO2(21%)	wet 60F	100W	0	24	
88Nov09	nsw1D12	60	90	HeO2(21%)	wet 60F	100W	0	26	
88Nov10	nsw1D13	60	90	HeO2(21%)	wet 60F	100W	0	5	
88Nov10	nsw1D13	60	90	HeO2(21%)	wet 60F	100W	0	18	
88Nov15	nsw1D14	60	90	HeO2(21%)	wet 60F	100W	0	1	
88Nov15	nsw1D14	60	90	HeO2(21%)	wet 60F	100W	0	26	
88Nov15	nsw1D14	60	90	HeO2(21%)	wet 60F	100W	0	4	
88Nov15	nsw1D15	60	90	HeO2(21%)	wet 60F	100W	0	17	
88Nov15	nsw1D15	60	90	HeO2(21%)	wet 60F	100W	0	3	
88Nov15	nsw1D15	60	90	HeO2(21%)	wet 60F	100W	0	31	
88Nov16	nsw1D16	60	90	HeO2(21%)	wet 60F	100W	0	29	
88Nov16	nsw1D16	60	90	HeO2(21%)	wet 60F	100W	0	24	
88Nov16	nsw1D16	60	90	HeO2(21%)	wet 60F	100W	0	18	
88Nov30	nsw1D17	60	90	HeO2(21%)	wet 60F	100W	0	17	
88Nov30	nsw1D17	60	90	HeO2(21%)	wet 60F	100W	0	14	
88Dec01	nsw1D18	60	100	HeO2(21%)	wet 60F	100W	0	5	
88Dec01	nsw1D18	60	100	HeO2(21%)	wet 60F	100W	0	1	
88Dec01	nsw1D19	60	100	HeO2(21%)	wet 60F	100W	0	24	
88Dec01	nsw1D19	60	100	HeO2(21%)	wet 60F	100W	0	10	
88Dec01	nsw1D19	60	100	HeO2(21%)	wet 60F	100W	0	26	
88Dec01	nsw1D18	60	100	HeO2(21%)	wet 60F	100W	0	29	
88Dec05	nsw1D20	60	100	HeO2(21%)	wet 60F	100W	0	4	
88Dec05	nsw1D20	60	100	HeO2(21%)	wet 60F	100W	0	31	
88Dec06	nsw1D21	60	100	HeO2(21%)	wet 60F	100W	0	17	
88Dec06	nsw1D21	60	100	HeO2(21%)	wet 60F	100W	0	14	
88Dec07	nsw1D22	60	110	HeO2(21%)	wet 60F	100W	0	26	
88Dec07	nsw1D22	60	110	HeO2(21%)	wet 60F	100W	0	33	
88Dec07	nsw1D22	60	110	HeO2(21%)	wet 60F	100W	0	34	
88Dec08	nsw1D23	60	110	HeO2(21%)	wet 60F	100W	0	5	

88Dec08	nsw1D23	60	110	HeO2(21%)	wet 60F	100W	0	24	
88Dec08	nsw1D23	60	110	HeO2(21%)	wet 60F	100W	0	10	
88Dec08	nsw1D24	60	110	HeO2(21%)	wet 60F	100W	0	29	
88Dec08	nsw1D24	60	110	HeO2(21%)	wet 60F	100W	0	1	
88Dec08	nsw1D24	60	110	HeO2(21%)	wet 60F	100W	0	19	
88Dec12	nsw1D25	60	120	HeO2(21%)	wet 60F	100W	0	17	
88Dec12	nsw1D25	60	120	HeO2(21%)	wet 60F	100W	0	16	
88Dec12	nsw1D25	60	120	HeO2(21%)	wet 60F	100W	0	30	
88Dec12	nsw1D26	60	120	HeO2(21%)	wet 60F	100W	0	31	
88Dec12	nsw1D26	60	120	HeO2(21%)	wet 60F	100W	1	14	#5
88Dec13	nsw1D27	60	120	HeO2(21%)	wet 60F	100W	0	33	
88Dec13	nsw1D27	60	120	HeO2(21%)	wet 60F	100W	n	18	#6
88Dec13	nsw1D27	60	120	HeO2(21%)	wet 60F	100W	n	34	#7
88Dec14	nsw1D28	60	120#8	HeO2(21%)	wet 60F	100W	0	15	#8
88Dec14	nsw1D28	60	120	HeO2(21%)	wet 60F	100W	1	24	#5
88Dec14	nsw1D28	60	120	HeO2(21%)	wet 60F	100W	2	1	#5
88Dec14	nsw1D29	60	120	HeO2(21%)	wet 60F	100W	0	26	
88Dec14	nsw1D29	60	120	HeO2(21%)	wet 60F	100W	0	4	

#1 See medical report. Rt elbow pain

#2 Location ?

#3 Shoulder.

#4 Transient itching arm after surfacing.

#5 See medical report

#6 Niggles

#7 Shoulder niggle

#8 Flooded helmet, locked out on descent.

#9 [EDT notes say air, but this was a heliox dive.]

Note: Diver #15 did not complete this dive, see note #8..

**Table 13. 40% oxygen dives to 60 fsw for 360 min. Dives E01-E14**  
Data set NSW1E. Found in NMRNSW2.

Date	File	Depth	Btime	Gas	Wet/dry	Work	DCS	Diver	#Notes
89Jan04	nsw1E01	60	240	N2-40%O2	wet 65F	100W	0	24	#1
89Jan04	nsw1E01	60	240	N2-40%O2	wet 65F	100W	0	21	
89Jan04	nsw1E01	60	240	N2-40%O2	wet 65F	100W	0	26	
89Jan05	nsw1E02	60	240	N2-40%O2	wet 65F	100W	0	35	
89Jan05	nsw1E02	60	240	N2-40%O2	wet 65F	100W	0	29	
89Jan05	nsw1E02	60	240	N2-40%O2	wet 65F	100W	0	10	
89Jan06	nsw1E03	60	240	N2-40%O2	wet 65F	100W	0	5	
89Jan06	nsw1E03	60	240	N2-40%O2	wet 65F	100W	0	3	
89Jan06	nsw1E03	60	240	N2-40%O2	wet 65F	100W	0	4	
89Jan09	nsw1E04	60	300	N2-40%O2	wet 65F	100W	0	8	
89Jan09	nsw1E04	60	300	N2-40%O2	wet 65F	100W	0	15	
89Jan09	nsw1E04	60	300	N2-40%O2	wet 65F	100W	0	21	
89Jan10	nsw1E05	60	300#2	N2-40%O2	wet 65F	100W	0	24	#2
89Jan10	nsw1E05	60	300	N2-40%O2	wet 65F	100W	0	30	
89Jan10	nsw1E05	60	300	N2-40%O2	wet 65F	100W	0	26	
89Jan11	nsw1E06	60	300	N2-40%O2	wet 65F	100W	0	35	#3
89Jan11	nsw1E06	60	300	N2-40%O2	wet 65F	100W	0	29	#3

89Jan11	nsw1E06	60	300	N2-40%O2	wet 65F	100W	0	36	#4
89Jan12	nsw1E07	60	300	N2-40%O2	wet 65F	100W	0	16	
89Jan12	nsw1E07	60	300	N2-40%O2	wet 65F	100W	0	37	#5
89Jan13	nsw1E08	60	360	N2-40%O2	wet 65F	75W	0	5	#6
89Jan13	nsw1E08	60	360	N2-40%O2	wet 65F	75W	0	3	#6
89Jan13	nsw1E08	60	360	N2-40%O2	wet 65F	75W	0	4	#6
89Jan17	nsw1E09	60	360	N2-40%O2	wet 65F	75W	0	8	#6
89Jan17	nsw1E09	60	360	N2-40%O2	wet 65F	75W	0	35	#6
89Jan17	nsw1E09	60	360	N2-40%O2	wet 65F	75W	0	21	#6
89Jan18	nsw1E10	60	360	N2-40%O2	wet 65F	75W	0	38	#6
89Jan18	nsw1E10	60	360	N2-40%O2	wet 65F	75W	0	29	#6
89Jan18	nsw1E10	60	360	N2-40%O2	wet 65F	75W	0	33	#6
89Jan19	nsw1E11	60	360	N2-40%O2	wet 65F	75W	0	24	#6
89Jan19	nsw1E11	60	360	N2-40%O2	wet 65F	75W	0	4	#6
89Jan23	nsw1E12	60	360	N2-40%O2	wet 65F	75W	0	8	#6
89Jan23	nsw1E12	60	360	N2-40%O2	wet 65F	75W	0	37	#6
89Jan23	nsw1E12	60	360	N2-40%O2	wet 65F	75W	0	14	#6
89Jan24	nsw1E13	60	360	N2-40%O2	wet 65F	75W	0	35	#6
89Jan24	nsw1E13	60	360	N2-40%O2	wet 65F	75W	0	15	#7
89Jan24	nsw1E13	60	360	N2-40%O2	wet 65F	75W	0	30	#6
89Jan27	nsw1E14	60	360ml	N2-40%O2	wet 65F	75W	0	17	#6
89Jan27	nsw1E14	60	360ml	N2-40%O2	wet 65F	75W	0	29	#6
89Jan27	nsw1E14	60	360ml	N2-40%O2	wet 65F	75W	0	33	#6

#1 "Spaced out" post dive, no fatigue, mentally tired only.

#2 Aborted at 2 hr, helmet problem.

#3 3-min descent.

#4 3-min descent, rt shoulder pain, trial tt5, no change, not DCS.

#5 Very fatigued postdive.

#6 Fluid replacement at 3 hr.

#7 Fluid replacement at 3 hr; wore only 1/8" wetsuit jacket, complained of cold 90 min into dive.

Note: Diver #24 left the dive at 2 hours, note #2.

**Table 14. Multiple repetitive wet dives with 40% oxygen, F01-F02.**

Data file NSW1F. Found in NMRNSW2.

Date	File	Depth	Btime	Gas	Wet/dry	Work	DCS	Diver	#Notes
89Jan25	nsw1F01	60	360ml	N2-40%O2	wet 65F	75W	0	5	#1
89Jan25	nsw1F01	60	360ml	N2-40%O2	wet 65F	75W	0	24	#1
89Jan25	nsw1F01	60	360ml	N2-40%O2	wet 65F	75W	0	4	#1
89Jan26	nsw1F02	60	360ml	N2-40%O2	wet 65F	75W	0	3	#2
89Jan26	nsw1F02	60	360ml	N2-40%O2	wet 65F	75W	0	34	#2
89Jan26	nsw1F02	60	360ml	N2-40%O2	wet 65F	75W	0	21	#2, #3

#1 Multilevel dive, get profile from log [or data base].

#2 Multilevel dive, get profile from log [or data base]. Gas switch 2nd sfc interval, not properly entered on computer.

#3 This man-dive not in Dr. Thalmann's log; data base shows only 2 divers. Inserted here from Conventional Log.

## 3. Profiles taken from data sets

Many of these dives have been entered into the NEDU data base and are available in electronic form. Printouts of the profiles available for this data report are included here.

Table 15. Profiles from NMRNSW2.DAT.

61.5, 81.5, 1.7, NSW1C01			61.5, 92.3, 1.4, NSW1C04			61.5, 92.1, 1.5, NSW1C08			61.5, 102.2, 1.3, NSW1C12		
1.0, 3, 0.0,			1.0, 1, 0.0,			1.0, 3, 0.0,			1.0, 1, 0.5, 227.0, 297.0,		
0.00, 0.0,			0.00, 0.0,			0.00, 0.0,			0.00, 0.0,		
4.00, 0.0,			1.20, 19.0,			3.50, 0.0,			3.00, 0.0,		
5.80, 61.5,			4.00, 39.0,			5.60, 61.5,			3.20, 0.0,		
14.00, 61.5,			5.20, 15.0,			95.70, 61.5,			3.40, 20.0,		
85.50, 61.5,			7.30, 0.0,			96.70, 7.5,			4.50, 38.0,		
86.10, 55.0,			17.40, 0.0,			97.10, 0.0,			5.30, 61.5,		
86.80, 10.0,			19.30, 56.0,			1537.10, 0.0,			19.30, 61.5,		
87.20, 0.0,			20.20, 61.5,			-9999.0			19.80, 56.0,		
1527.20, 0.0,			109.60, 61.5,			61.5, 92.1, 1.3, NSW1C09			28.30, 56.0,		
-9999.0			109.80, 51.5,						28.60, 61.5,		
61.5, 83.7, 1.3, NSW1C02			110.70, 7.5,						105.40, 61.5,		
			111.10, 0.0,			1.0, 2, 0.0,			106.40, 7.5,		
1.0, 3, 0.0,			1551.10, 0.0,			0.00, 0.0,			106.70, 0.0,		
0.00, 0.0,			-9999.0			3.70, 0.0,			1546.70, 0.0,		
4.00, 0.0,			61.5, 92.3, 1.2, NSW1C05			5.70, 61.5,			-9999.0		
5.10, 42.0,						95.80, 61.5,			61.5, 102.4, 1.1, NSW1C13		
5.40, 38.0,			1.0, 3, 0.0,			96.90, 7.5,					
6.50, 56.0,			0.00, 0.0,			97.20, 0.0,			1.0, 1, 0.0,		
7.10, 56.0,			3.80, 0.0,			1537.20, 0.0,			0.00, 0.0,		
8.10, 61.5,			6.00, 61.5,			-9999.0			4.40, 0.0,		
87.60, 61.5,			96.10, 61.5,			61.5, 92.2, 1.3, NSW1C10			5.70, 30.0,		
87.80, 56.5,			96.20, 51.5,						6.30, 50.0,		
88.30, 20.5,			97.10, 7.5,			1.0, 2, 0.0,			6.70, 61.5,		
88.60, 7.5,			97.30, 0.0,			0.00, 0.0,			106.80, 61.5,		
88.90, 0.0,			1537.30, 0.0,			2.70, 0.0,			107.70, 9.5,		
1528.90, 0.0,			-9999.0			4.80, 61.5,			107.90, 0.0,		
-9999.0			61.5, 91.9, 1.2, NSW1C06			94.90, 61.5,			1547.90, 0.0,		
61.5, 82.3, 1.1, NSW1C03						95.80, 7.5,			-9999.0		
			1.0, 2, 0.0,			96.10, 0.0,			61.5, 102.4, 1.1, NSW1C13		
1.0, 2, 0.0,			0.00, 0.0,			1536.10, 0.0,					
0.00, 0.0,			4.40, 0.0,			-9999.0			1.0, 1, 0.5, 117.9, 137.9,		
2.50, 0.0,			6.30, 61.5,			61.5, 91.9, 1.1, NSW1C11			0.00, 0.0,		
4.30, 56.0,			96.30, 61.5,						4.40, 0.0,		
5.80, 61.5,			97.30, 9.5,			1.0, 2, 0.0,			5.70, 30.0,		
84.80, 61.5,			97.50, 0.0,			0.00, 0.0,			6.30, 50.0,		
85.10, 51.5,			1537.50, 0.0,			4.80, 0.0,			6.70, 61.5,		
85.70, 9.5,			-9999.0			5.20, 15.0,			106.80, 61.5,		
85.90, 0.0,			61.5, 91.9, 1.2, NSW1C06			6.50, 61.5,			107.70, 9.5,		
1525.90, 0.0,						96.70, 61.5,			107.90, 0.0,		
-9999.0			1.0, 1, 1.0, 127.5, 217.5,			97.60, 7.5,			1547.90, 0.0,		
61.5, 82.3, 1.1, NSW1C03						97.80, 0.0,			-9999.0		
			0.00, 0.0,			1537.80, 0.0,			61.5, 106.1, 1.3, NSW1C14		
1.0, 1, 0.5, 206.0, 266.0,			4.40, 0.0,			-9999.0					
0.00, 0.0,			6.30, 61.5,			61.5, 102.2, 1.3, NSW1C12			1.0, 2, 0.0,		
2.50, 0.0,			96.30, 61.5,						0.00, 0.0,		
4.30, 56.0,			97.30, 9.5,			1.0, 2, 0.0,			4.10, 0.0,		
5.80, 61.5,			97.50, 0.0,			0.00, 0.0,			4.80, 18.0,		
84.80, 61.5,			1537.50, 0.0,			3.00, 0.0,			5.30, 13.0,		
85.10, 51.5,			-9999.0			3.20, 0.0,			6.10, 13.0,		
85.70, 9.5,			61.5, 92.1, 1.2, NSW1C07			3.40, 20.0,			6.50, 21.0,		
85.90, 0.0,						4.50, 38.0,			7.60, 21.0,		
1525.90, 0.0,			1.0, 2, 0.0,			5.30, 61.5,			8.90, 56.0,		
-9999.0			0.00, 0.0,			105.40, 61.5,			10.20, 56.0,		
			4.10, 0.0,			106.40, 7.5,			11.20, 61.5,		
			6.10, 61.5,			106.70, 0.0,			110.20, 61.5,		
			96.20, 61.5,			1546.70, 0.0,			110.60, 41.5,		
			97.10, 9.5,			-9999.0			111.20, 7.5,		
			97.30, 0.0,						111.50, 0.0,		
			1537.30, 0.0,						1551.50, 0.0,		
			-9999.0						-9999.0		

61.5, 106.1, 1.3, NSW1C14	61.5, 92.2, 1.2, NSW1C17	61.5, 242.3, 1.2, NSW1E01	61.5, 304.3, 1.1, NSW1E06
1.0, 1, 1.0, 141.5, 204.5,	1.0, 2, 0.0,	1.0, 3, 0.0,	1.0, 2, 0.0,
0.00, 0.0,	0.00, 0.0,	0.00, 0.00, 2.40, 0.5	0.00, 0.00, 2.40, 0.5
4.10, 0.0,	4.20, 0.0,	10.30, 0.00,	4.80, 0.00,
4.80, 18.0,	4.90, 20.0,	12.40, 61.50,	7.40, 56.00,
5.30, 13.0,	6.30, 61.5,	252.50, 61.50,	9.00, 56.00,
6.10, 13.0,	96.50, 61.5,	252.80, 41.50,	10.00, 61.50,
6.50, 21.0,	96.90, 31.5,	253.10, 19.50,	309.00, 61.50,
7.60, 21.0,	97.40, 9.5,	253.40, 8.50,	310.00, 8.50,
8.90, 56.0,	97.70, 0.0,	253.80, 0.00,	310.10, 0.00,
10.20, 56.0,	1537.70, 0.0,	254.47, 0.00, 1.0, 0.5	310.68, 0.00, 1.0, 0.5
11.20, 61.5,	-9999.0	1694.47, 0,	1750.68, 0,
110.20, 61.5,	61.5, 92.2, 1.2, NSW1C17	-9999.0	-9999.0
110.60, 41.5,		61.5, 242.2, 1.5, NSW1E02	61.5, 303.2, 1.4, NSW1E07
111.20, 7.5,	1.0, 1, 1.0, 217.7, 608.,		
111.50, 0.0,		1.0, 3, 0.0,	1.0, 1, 0.0,
1551.50, 0.0,	0.00, 0.0,		
-9999.0	4.20, 0.0,	0.00, 0.00, 2.40, 0.5	0.00, 0.00, 2.40, 0.5
61.5, 101.6, 1.3, NSW1C15	4.90, 20.0,	4.30, 0.00,	3.30, 0.00,
	6.30, 61.5,	4.60, 20.00,	6.30, 61.50,
1.0, 2, 0.0,	96.50, 61.5,	6.50, 61.50,	306.50, 61.50,
	96.90, 31.5,	246.50, 61.50,	307.00, 41.50,
0.00, 0.0,	97.40, 9.5,	247.60, 4.00,	307.40, 17.50,
5.70, 0.0,	97.70, 0.0,	248.00, 0.00,	307.60, 7.50,
7.30, 61.5,	1537.70, 0.0,	249.20, 0.00, 1.0, 0.5	307.80, 0.00,
107.30, 61.5,	-9999.0	1689.20, 0,	308.33, 0.00, 1.0, 0.5
108.00, 21.5,	61.5, 84.2, 1.2, NSW1C18	-9999.0	1748.33, 0,
108.20, 11.5,		61.5, 242.8, 1.0, NSW1E03	-9999.0
108.40, 7.5,	1.0, 3, 0.0,		61.5, 303.2, 1.4, NSW1E07
108.60, 0.0,		1.0, 3, 0.0,	
1548.60, 0.0,	0.00, 0.0,		1.0, 1, 0.5, 337.8, 362.8,
-9999.0	4.00, 0.0,	0.00, 0.00, 2.40, 0.5	0.00, 0.00, 2.40, 0.5
61.5, 102.1, 1.2, NSW1C16	4.50, 15.0,	4.00, 0.00,	3.30, 0.00,
	5.10, 15.0,	4.40, 8.00,	6.30, 61.50,
1.0, 1, 0.0,	5.30, 25.0,	6.80, 61.50,	306.50, 61.50,
	6.30, 25.0,	246.80, 61.50,	307.00, 41.50,
0.00, 0.0,	7.30, 55.0,	247.40, 19.50,	307.40, 17.50,
3.40, 0.0,	8.10, 61.5,	247.80, 0.00,	307.60, 7.50,
4.00, 20.0,	88.20, 61.5,	248.23, 0.00, 1.0, 0.5	307.80, 0.00,
4.60, 42.0,	89.10, 11.5,	1688.23, 0,	308.33, 0.00, 1.0, 0.5
5.40, 61.5,	89.30, 0.0,	-9999.0	1748.33, 0,
105.50, 61.5,	1529.30, 0.0,	61.5, 302.2, 1.4, NSW1E04	-9999.0
105.90, 41.5,	-9999.0		61.5, 363.1, 1.2, NSW1E08
106.50, 9.5,	61.5, 82.3, 1.1, NSW1C19	1.0, 3, 0.0,	
106.70, 0.0,			1.0, 3, 0.0,
1546.70, 0.0,	1.0, 1, 0.0,	0.00, 0.00, 2.40, 0.5	0.00, 0.00, 2.40, 0.5
-9999.0	0.00, 0.0,	5.80, 0.00,	3.90, 0.00,
61.5, 102.1, 1.2, NSW1C16	2.70, 0.0,	7.40, 50.00,	6.90, 61.50,
	4.40, 54.0,	8.00, 61.50,	367.00, 61.50,
1.0, 1, 0.5, 226.7, 1546.7,	5.30, 61.5,	308.00, 61.50,	367.60, 21.50,
	85.00, 61.5,	308.90, 8.50,	368.00, 7.50,
0.00, 0.0,	85.90, 11.5,	309.30, 0.00,	368.20, 0.00,
3.40, 0.0,	86.10, 0.0,	310.00, 0.00, 1.0, 0.5	369.02, 0.00, 1.0, 0.5
4.00, 20.0,	1526.10, 0.0,	1750.00, 0,	1809.02, 0,
4.60, 42.0,	-9999.0	-9999.0	-9999.0
5.40, 61.5,	61.5, 82.3, 1.1, NSW1C19	61.5, 302.0, 1.3, NSW1E05	61.5, 363.2, 2.3, NSW1E09
105.50, 61.5,			
105.90, 41.5,	1.0, 1, 1.0, 96.1, 121.1,	1.0, 2, 0.0,	1.0, 3, 0.0,
106.50, 9.5,			
106.70, 0.0,		0.00, 0.00, 2.40, 0.5	0.00, 0.00, 2.40, 0.5
1546.70, 0.0,	0.00, 0.0,	5.50, 0.00,	3.80, 0.00,
-9999.0	2.70, 0.0,	7.50, 61.50,	6.90, 61.50,
61.5, 102.1, 1.2, NSW1C16	4.40, 54.0,	307.50, 61.50,	367.00, 61.50,
	5.30, 61.5,	308.10, 21.50,	368.00, 7.50,
1.0, 1, 1.0, 226.7, 467.,	85.00, 61.5,	308.50, 7.50,	369.20, 0.00,
	85.90, 11.5,	308.80, 0.00,	370.38, 0.00, 1.0, 0.5
0.00, 0.0,	86.10, 0.0,	309.18, 0.00, 1.0, 0.5	1810.38, 0,
3.40, 0.0,	1526.10, 0.0,	1749.18, 0,	-9999.0
4.00, 20.0,	-9999.0	-9999.0	
4.60, 42.0,			
5.40, 61.5,			
105.50, 61.5,			
105.90, 41.5,			
106.50, 9.5,			
106.70, 0.0,			
1546.70, 0.0,			
-9999.0			

61.5, 363.1, 1.2, NSW10	61.5, 93.1, 1.1, NSW101	61.5, 93.1, 1.2, NSW102
1.0, 3, 0.0,	1.0, 3, 0.0,	1.0, 2, 0.0,
0.00, 0.00, 2.40, 0.5	0.00, 0.00, 2.40, 0.5	0.00, 0.0, 2.40, 0.5
2.50, 0.00,	3.30, 0.0,	4.80, 0.0,
5.50, 61.50,	6.30, 61.5,	7.80, 61.5,
365.60, 61.50,	96.40, 61.5,	97.90, 61.5,
365.80, 51.50,	97.20, 11.5,	98.70, 11.5,
366.50, 11.50,	97.50, 0.0,	99.10, 0.0,
366.60, 8.50,	99.20, 0.0, 1.00, 0.5	100.90, 0.0, 1.00, 0.5
366.80, 0.00,	114.20, 0.0, 2.40, 0.5	115.50, 0.0, 2.40, 0.5
367.13, 0.00, 1.0, 0.5	116.30, 0.0,	117.90, 0.0,
1807.13, 0,	119.30, 61.5,	121.20, 61.5,
-9999.0	209.60, 61.5,	211.30, 61.5,
61.5, 360.1, 1.1, NSW11	210.50, 10.0,	212.10, 10.0,
1.0, 2, 0.0,	210.80, 0.0,	212.40, 0.0,
0.00, 0.00, 2.40, 0.5	212.50, 0.0, 1.00, 0.5	214.30, 0.0, 1.00, 0.5
3.80, 0.00,	227.60, 0.0, 2.40, 0.5	229.30, 0.0, 2.40, 0.5
9.10, 61.50,	229.60, 0.0,	231.30, 0.0,
369.10, 61.50,	232.50, 61.5,	234.00, 61.5,
369.90, 11.50,	322.60, 61.5,	324.40, 61.5,
370.20, 0.00,	323.50, 10.0,	325.40, 10.0,
370.60, 0.00, 1.0, 0.5	323.80, 0.0,	325.60, 0.0,
1810.60, 0,	325.50, 0.0, 1.00, 0.5	327.40, 0.0, 1.00, 0.5
-9999.0	340.10, 0.0, 2.40, 0.5	342.60, 0.0, 2.40, 0.5
61.5, 362.6, 1.2, NSW12	342.60, 0.0,	344.50, 0.0,
1.0, 3, 0.0,	345.60, 61.5,	347.50, 61.5,
0.00, 0.00, 2.40, 0.5	436.00, 61.5,	437.60, 61.5,
9.40, 0.00,	436.90, 10.0,	438.50, 10.0,
9.70, 15.00,	437.20, 0.0,	438.80, 0.0,
10.30, 18.00,	438.30, 0.0, 1.00, 0.5	440.30, 0.0, 1.00, 0.5
11.80, 61.50,	1878.30, 0,	1880.30, 0,
372.00, 61.50,	-9999.0	-9999.0
372.90, 11.50,		
373.10, 0.00,		
374.05, 0.00, 1.0, 0.5		
1814.05, 0,		
-9999.0		
61.5, 362.2, 1.1, NSW1E13		
1.0, 3, 0.0,		
0.00, 0.00, 2.40, 0.5		
4.20, 0.00,		
6.30, 61.50,		
366.40, 61.50,		
366.90, 26.50,		
367.20, 10.50,		
367.50, 0.00,		
367.93, 0.00, 1.0, 0.5		
1807.93, 0,		
-9999.0		
61.5, 363.9, 1.1, NSW1E14		
1.0, 3, 0.0,		
0.00, 0.00, 2.40, 0.5		
2.80, 0.00,		
6.70, 61.50,		
366.70, 61.50,		
367.40, 21.50,		
367.60, 10.50,		
367.80, 0.00,		
368.63, 0.00, 1.0, 0.5		
1808.63, 0,		
-9999.0		



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## D. Medical Reports

Medical officers normally prepare a short narrative report following each treatment for decompression illness. We have included 18 of these on the following pages. Diver names have been replaced with diver numbers shown on each page.

One case, 1989 Jan 12, for Diver #36 was determined to be mechanical and the diver did not have decompression sickness.

There were a total of 24 cases of decompression sickness in the dive series. Most of these are mentioned in the logs by Dr. Thalmann, section C.2. For the cases not covered in the Medical Reports these brief notes are all the information available.

Medical reports are available for the following divers, including date of medical report. In some cases the dive was a day or two before the report date.

Diver	Date
1	1988 Jun 02
1	1988 Dec 14
2	1988 Oct 20
4	1988 Oct 13
4	1988 Dec 15
5	1988 Sep 27
5	1988 Oct 05
9	1988 May 24
11	1988 May 24
12	1988 Jun 17
14	1988 Jun 02
14	1988 Dec 14
19	1988 Jun 06
21	1988 May 24
21	1988 Oct 26
25	1988 Jun 06
26	1988 Dec 15
36	1989 Jan 12

# SUMMARY REPORT OF HYPERBARIC THERAPY

## SUMMARY OF HYPERBARIC TREATMENT

DATE: 2 JUN 1988

PATIENT:

### REASON FOR TREATMENT: DECOMPRESSION SICKNESS; TYPE I

SUMMARY: Subject participated in experimental dive to 60 feet for 100 minutes on H<sub>2</sub>O<sub>2</sub> at 79/21. Experimental dive left surface at 1042 and reached surface at 1234. When evaluated at one hour post dive, subject had been asymptomatic. At 1400 (plus 1.5 hr) subject had pain in right arm that was localized to mid-triceps and elicited by palpation and movement. Also had some discomfort in same area of left triceps. Neurologic exam revealed no other abnormalities. During recompression to 60 feet which started at 1449, subject had complete resolution of symptoms at 48 feet. Symptoms did not reappear. Treatment was completed according to US Navy Table 5. Patient was asymptomatic and had normal physical exam at 1710 (one hour after end of treatment).

IMPRESSION: Decompression Sickness, Type I; successfully treated with Table 5

Date of treatment: 14 December 1988

On 14 December 1988 the patient surfaced from an uneventful "No D" dive to 60 fsw for 120 minutes breathing a 79/21 mix of H<sub>2</sub>O<sub>2</sub> as a participant in NHRI protocol 88-06A. The patient experienced transient, migratory joint pains, "niggles", until 2000 hrs when he noted a persistent, dull pain in his right shoulder. The pain continued and symptoms progressed over the next 120 minutes to include left hip and lower back pain, confusion, mood swings and a "weird" sensation of swimming. He denied experiencing a sensation of motion and described his mood swings as feeling as if he was going to cry but without any reason for doing so. He called NHRI and was evaluated by me at approximately 2245 hours.

... appeared fatigued, confused, and spoke in a slow, depressed fashion with eyes downcast. During the exam he started crying while expressing confusion as to why he was doing so. He also complained of nausea and vomited twice during the examination.

On examination of the cranial nerves hypersaccadic, hypermetric movement of the eyes was apparent. The other cranial nerves appeared normal. Sensory was grossly intact to pinwheel. Motor testing revealed marked reduction of strength of the right upper and lower extremities (4+ versus 5+ for the left side). The reflexes appeared symmetric and of normal intensity. Cerebellar testing demonstrated past pointing of the right upper extremity on the finger to nose maneuver. Rapid alternating movements of the right upper extremity were sloppy and slow. The rest of the exam was deferred as the chamber and crew was ready to begin treatment at this point. The patient was unable to walk to the chamber due to the now marked weakness of his right lower extremity. He was assisted to the chamber and a U.S. Navy Treatment Table 6 was initiated.

At depth a 20 gauge intravenous catheter was inserted and one liter of D51/2M5 was infused rapidly. Decadron 12mg was given intravenously over 20 minutes and a hematocrit was sent and returned at 50%. During the first air break the patient stated that the mood shift and nausea were relieved; however, he still felt confused and anxious. Examination by HMI Baker noted hypermetric saccades, weakness and hyperreflexia of the right side and dysmetric movements of the right upper extremity on finger to nose testing.

During the second air break the patient stated that his confusion had improved 50% and that the right shoulder pain was completely gone. The left hip pain was 95% relieved. Examination demonstrated hypermetric saccades, muscle strength equal and normal, reflexes 2+ and symmetric and normal finger to nose maneuver and rapid

alternating movements of right upper extremity.

Seven minutes into the first extension at 60 fsw (fourth oxygen breathing period at 60 fsw) the patient stated that he had complete relief of all confusion, "light headedness", and joint pain. Examination revealed normal eye movements, muscle strength, reflexes, finger to nose and rapid alternating movements testing.

The patient completed three extensions at 60 fsw and two extensions at 30 fsw. He continued to have no complaints and normal neurologic examinations. He received a total of 3000 cc of intravenous fluid in addition to oral fluid and voided 1050 cc of urine which changed from dark amber to clear over the course of the treatment.

Decadron 4 mg was administered slow IV push every four hours. Psychomotor testing was performed during the course of the treatment (started during fourth air break and ended during the first air break at 30 fsw), and at the surface. The results are tabulated below and are compared with pre-dive values. Post treatment values are at least as good as pre-dive values. An examination was performed prior to leaving 60 fsw by the DMO and was found to be normal.

At the surface the patient had no complaints and had a normal neurologic examination. When questioned about symptoms of oxygen toxicity he stated that his lungs felt irritated. His total & loss of FVC was calculated to be 7.6. He was evaluated by CDR Dutka, Head Medicine Dept. NMRI-DMD and staff neurologist at NHBETH, and found to have no significant abnormalities. An MRI scan was performed and the results are pending as of the date of this report. The patient was examined again on 16 December 1988 and again was found to be neurologically intact and without complaints.

IMPRESSION: Type II Decompression sickness involving the brainstem. Complete relief following modified US NAVY TT6 with 3 extensions at 60 fsw and 2 extensions at 30 fsw. MRI scan results pending. Continue decadron 4 mg PO for a total of 48 hours and NPQ diving status for 2 months.

*Forrest A. Hume*

TABLE I: Psychomotor Testing Results

	Baseline	During Rx	Post Rx(15 DEC 88)
digits(forward/back)	6/4	5/3	5/3
trailmaking(a/b)	31/58	28/57	22/60
digit symbol	54	51	62
logical memory	8.3=5.5	4.4=4	7.9=8
figural memory	10	7	11
associative memory	14.5	11	21

# Summary of Hyperbaric Treatment

DATE: 20 October, 1988

On 20 October, 1988, [redacted] was involved in a 60 fsw/80 min air "No p" dive. The dive was uneventful and both divers were OK at the 30 minute check. At approximately 35 minutes after the dive [redacted] complained of a pain stimulating muscle spasm of his left flank. He reported to sickbay. Over the course of 3-5 minutes his symptoms progressed to include parasthesias of the left side from the left toes to the left chest and back above the nipple line, muscle weakness of the left lower extremity (quadriceps 3/5 according to corpsman's exam, gait grossly affected), perioral numbness and drooling. In the chamber just prior to descent the patient felt lightheaded but denied true vertiginous symptoms. He did not lose consciousness. Due to the severity and rapid progression of symptoms a full neurologic exam was not performed on the surface. Recompression proceeded on 100% oxygen to 60 fsw IAW TT6 as outlined in the U.S. Navy Dive Manual. The patient had complete relief after 1 minute at the bottom. Two extensions at 60 fsw were performed.

At depth vital signs were BP 130/90, P 60 regular, and respirations 16/min. An 18 ga. IV was introduced and NS at a rate of 150 cc/hr was started following a 500cc bolus. Decadron 10 mg slow IVP was given without incident. A full neurologic exam at 60 fsw was normal. Neuro exam performed just prior to leaving 60 fsw, upon arrival at 30 fsw and at the surface were normal. The patient voided just prior to leaving 60 fsw. Total I/O: 2700/1921. Prior to fluid resuscitation a spin hematocrit was 43.

After reaching the surface the patient performed psychomotor testing. The results were unchanged from baseline. The patient was examined by the duty resident neurologist at NHEHH and no abnormalities were found. An IM dose of Decadron 6mg was given. The patient was followed at NMRI with Qib checks and the next morning he remained without complaints with a normal neurologic exam.

-- should not dive for four (4) weeks.

IMPRESSION: TYPE II DCS MOST LIKELY INVOLVING BRAIN STEM OR CERVICAL/UPPER THORACIC SPINAL CORD

*Dr. M. H. H.*

#2

## SUMMARY OF HYPERBARIC TREATMENT

DATE: 22 October, 1988

dove on Oct. 20, 1988 to 60 fsw for 80 min. without decompression. Thirty-five minutes after surfacing he had onset of symptoms of left sided parasthesias, left leg muscle weakness, perioral numbness and lightheadedness. The patient was treated with a treatment table six with two extensions at 60 fsw. Full recovery was documented with a normal post treatment neurologic exam, evoked potentials and psychomotor testing.

The patient states that on 21 Oct. he felt fatigued but otherwise felt normal. He slept well on the night of the 21st but awoke at 0700 22 Oct. and noted "pins and needles" of his left buttocks, lateral left leg extending to the dorsal and plantar surfaces of the foot. He described the feeling as if his leg were asleep. The sensation remained unchanged throughout the day. The patient specifically denies any long car rides, bike trips or other activity which might cause nerve compression. As well, he denies muscle weakness or any other symptoms except that on the way to NMRI he felt that his thinking was cloudy--an inability to concentrate.

At the time of his exam at NMRI (1600) his only complaint was the subjective sensations as described above. The neuro exam was completely normal including sensory modalities of light touch, pinprick, position, and vibratory. There was no extinction to bilateral stimulation and stereognostic testing was normal.

IMPRESSION: Subjective parasthesias of the left side from the buttocks to the left foot 35 hours following treatment for type II DCS with complete resolution. The distribution is not completely consistent with a dermatomal pattern. The etiology of symptoms is most likely post injury inflammation, ischemia or hemorrhage. The patient was treated with a straight TT6. There was no improvement in symptoms. The patient was sent home on Motrin 800 mg tid. The current plan is to repeat evoked responses and obtain an MRI scan.

*Dr. M. H. H.*

IMPRESSION: Recurrent symptoms following Type II DCS, etiology unclear.

*Dr. M. H. H.*

# SUMMARY OF HYPERBARIC TREATMENT

DATE: 23 October, 1988

The patient was originally treated on 20 Oct., 1988 for Type II DCS or paradoxical AGE following an experimental 60 fsw/80 min "No D" dive on NMRI protocol 88-06. On 22 Oct., 1988 he was treated for a sensation of "pins and needles" from the left buttocks and left lateral leg to the left foot. Neurologic exam was completely normal both before and after the treatment; however there was no resolution of the sensation as described above. The patient was given Motrin 800 mg tid overnight and was found to be unchanged the next morning. The decision was made to attempt another hyperbaric trial. The etiology of the recurrence of symptoms remains unclear and may represent inflammation, ischemia, infarct or hemorrhage. Hyperbaric oxygen may have a positive effect on inflammation and ischemia although this remains a source of great controversy.

The patient was treated on a RT6 which was modified due to symptoms consistent with pulmonary oxygen toxicity. At sixty feet the patient began to complain of chest pain with deep inspiration during the second oxygen period. The third oxygen period was spent at 45 fsw. The patient reported pain with normal respiratory excursions during the second oxygen period at 30 fsw and therefore was started towards the surface at a rate of 1 fsw/minute. The patient was given an initial dose of decadron 12 mg IM prior to entering the chamber and 4 mg IM Q 4 hours thereafter.

On the surface the patient reported only mild irritation of his lungs. He had a slight cough with deep inspiration and his lungs were clear to auscultation. His sensation of "pins and needles" remained unchanged. His neuro exam was unremarkable with completely normal sensory testing to pinprick, light touch, cold, vibratory and position. There was no extinction to bilateral stimuli and stereognostic testing was normal.

On 24 Oct., 1988 the patient reported that his symptoms were essentially the same, perhaps slightly less apparent than the previous day. He was started on an oral prednisone taper and the IM decadron was discontinued.

On 24 Oct., 1988 the patient was scheduled to be evaluated in the neurology clinic of NHBETH. The current plan is to repeat his evoked responses and obtain an MRI scan of his brain, cervical and upper thoracic cord.

# UPDATE ON TYPE II DCS

D. 4: 1 November, 1988

--- was treated initially for Type II DCS on 20 October, 1988. He gained complete relief within 1 1/2 minutes of reaching the bottom and was treated on an extended TT6. On 22 October, 1988, reported sensory abnormalities of the left leg. He was treated on 22 October with a TT6 but no effect benefit was obtained. He was treated again on 23 October with a TT6 modified due to symptoms of pulmonary oxygen toxicity. A neurologist was consulted and no objective neurologic finding were found. Brainstem Auditory Evoked Potentials and Somatosensory Evoked Potentials were normal. An MRI scan of the brain and cervical-upper thoracic spinal cord was performed and was normal. A contrast echocardiogram was normal. --- reported complete relief of symptoms on 25 October, 1988. He continues to be without complaints at the time of this report.

Due to the unusual nature of --- symptoms, rapid progression and apparent late onset of residual symptoms it is prudent to keep him out of diving for a period of five months.

*Spence*

#2

## SUMMARY OF HYPERBARIC TREATMENT

PATIENT: 13 OCTOBER 1988  
 TRTMT DATE: 88-06  
 PROTOCOL: 60'/90 MINUTES, AIR  
 DIVE: 12:58 12 OCTOBER 1988  
 LS: 14:28  
 RS: TYPE I DECOMPRESSION SICKNESS, INVOLVING  
 DIAGNOSIS: SYMPTOMS OF RIGHT MEDIAL KNEE PAIN

Patient presented at 01:20 after serving as a subject on a 60' for 90 minute dive, complaining of 3 hours of persistent right medial knee pain, present at rest, and unaffected by movement or manipulation. Except for mild general muscular fatigue, he had no other symptoms and recalled no injury during or after the dive. By the time the initial examination was completed, the pain had diminished from 5/10 to 3/10.

The patient was alert and fully oriented. Cranial nerves, strength, gait, sensation, and reflexes were all intact and symmetric. There was full range of motion in all extremities, with no swelling erythema, crepitus, or external injury.

Recompression to 60' was begun at 01:48. The patient reported complete relief at 10 minutes and 30 seconds at 60 feet. A TT5 was elected because of the mild nature of the initial symptoms. Treatment was completed at 04:05. Re-examination revealed complete resolution of all symptoms.

#4

# SUMMARY OF HYPERBARIC TREATMENT

Date of Treatment: 15 December 1988

On 14 December 1988 the patient surfaced from an uneventful "No D" dive to 60 fsw for 120 minutes breathing a 79/21 mix of HEO2 as a participant in NMRI protocol 88-06A. The patient experienced a transient headache at depth that lasted less than 30 minutes and did not recur. He noted transient pains, "niggles", in his elbows and right wrist which lasted less than 10 minutes and resolved spontaneously. At the 24 hour check STCS Ryan stated that he was fatigued, had trouble concentrating on the SF 9940 which he filled out on the morning of 15 December 1988, and had a transient rash with mild itching on the right forearm which resolved spontaneously. A neuro exam was performed and was completely normal including the mental status exam. Psychomotor testing was performed and was unchanged from baseline. A U.S. Navy treatment table 5 was performed. After completion of the treatment the patient stated that the tired feeling in his thighs was improved but otherwise there was no change.

IMPRESSION: TRANSIENT MUSCULOSKELETAL PAIN AND SUBJECTIVE MENTAL STATUS COMPLAINTS PROBABLY NOT RELATED TO DECOMPRESSION SICKNESS AND WITHOUT IMPROVEMENT FOLLOWING U.S. NAVY TREATMENT TABLE 5.

*Quincy H. Hume*

27 SEPTEMBER 1988

## SUMMARY OF HYPERBARIC TREATMENT

PATIENT: 27 SEPTEMBER 1988  
 DATE: 88-06  
 PROTOCOL: 60' FOR 90 MINUTES, AIR  
 DIVE: 09:18 27 SEPTEMBER 1988  
 LS: 10:52  
 RS: TYPE I DCS  
 DIAGNOSIS:

Patient presented 3 hours after dive complaining of diffuse left upper arm pain (dull ache, present at rest, unaffected by movement) that began at 13:00, increased over 30 minutes, and remained constant thereafter. No other symptoms. Dive profile and activity at bottom had been unremarkable and not suggestive of any mechanical injury.

Neurologic exam was normal. Left arm was normal in appearance, there was full range of motion, joint stability, and strength. There was no tenderness on palpation.

Recompression to 60' produced complete resolution of the symptoms at 57 seconds after reaching bottom. Treatment table 5 was completed at 16:45. Subject was re-examined on surface at 17:15 and found to be neurologically normal and without symptoms. Patient was observed for one hour.

*THH*



## SUMMARY REPORT OF HYPERBARIC THERAPY

#9.

DATE: 24 MAY 1988

PATIENT: -  
SEX: MALE

## REASON FOR TREATMENT: TYPE I DECOMPRESSION SICKNESS

SUMMARY: This patient participated in a dive for research protocol 88-06. The dive required 120 minutes of bottom time at 60 fsw with intermittent periods of exercise at 100 watts on a cycle ergometer. The divers left the surface at 0911 and reached surface at 1122. Breathing media was 79/21 helium/oxygen. Pre-dive history and physical revealed no abnormalities and no reason to not participate in the dive. There were five divers in the protocol. This patient plus two others subsequently developed symptoms that were diagnosed as Type I decompression sickness and all were treated under USN Treatment Table 6 beginning at 1243 (81 minutes after surfacing).

This patient was asymptomatic when he reached the surface, and when evaluated at 1155 (+ 33 minutes). At +65 minutes he developed pain in the right shoulder. His physical exam revealed no other signs nor symptoms and the neurological exam was normal. During recompression, symptoms disappeared at 46 fsw and did not recur. Treatment was completed according to Table 6, and the patient emerged with no signs nor symptoms of decompression sickness.

IMPRESSION: Type I decompression sickness, treated by recompression according to USN Table 6

## SUMMARY OF HYPERBARIC TREATMENT

#5

PATIENT: 05 OCTOBER 1988  
TREATMENT DATE: 88-06  
PROTOCOL: 60'/100 MINUTES  
DIVE: 11:22 05 OCTOBER 1988  
LS: 13:10  
RS: 13:10

DIAGNOSIS: TYPE II DECOMPRESSION SICKNESS, PRIMARILY INVOLVING SYMPTOMS CONSISTENT WITH RADIAL NERVE ISCHEMIA

Patient presented at 14:53 after serving as a subject on a 60' for 100 minute dive complaining of numbness of right upper arm and extensor surface of right wrist, forefinger, and thumb. This began at 14:43 at rest and progressed over 10 minutes enough for him to seek medical attention. He also complained of general fatigue, had no specific weakness or pain. During the pre-dive examination, he had complained of mild right shoulder discomfort from an athletic injury, but he recalled no injury during the dive.

The patient appeared fatigued, and there was a flat, erythematous rash over the right pectoral area. Neurologic exam revealed that he was alert and oriented. There was full and symmetric strength in all extremity muscle groups, although the patient complained that his right elbow extensors felt less reliable and less sensitive to force feedback than the left. Sensation was normal to light touch and pinprick, although he complained that the extensor surfaces of the right wrist, thumb, and forefinger felt generally less sensitive than the left. Reflexes were all normal and unchanged from baseline examinations. Gait was normal.

Recompression to 60' was begun at 15:07. The patient reported complete relief at 15:24. An unextended RT6 was completed at 19:56. Examination revealed complete resolution of all complaints and the rash. Neurologic examination was normal.

As of 07 October there was no recurrence.

## SUMMARY REPORT OF HYPERBARIC THERAPY

DATE: 24 MAY 1988

PATIENT: HTC(DV)  
SEX: MALE STATUS: .

## REASON FOR TREATMENT: TYPE I DECOMPRESSION SICKNESS

SUMMARY: This patient participated in a dive for research protocol 88-06. The dive required 120 minutes of bottom time at 60 fsw with intermittent periods of exercise at 100 watts on a cycle ergometer. The divers left the surface at 0911 and reached surface at 1122. Breathing media was 79/21 helium/oxygen. Pre-dive history and physical revealed no abnormalities and no reason to not participate in the dive. There were five divers in the protocol. This patient plus two others subsequently developed symptoms that were diagnosed as Type I decompression sickness and all were treated under USN Treatment Table 6 beginning at 1243 (81 minutes after surfacing).

This patient had no complaints and his physical exam was normal at 1154 (+32 minutes). At 1219 (+57 minutes) he complained of pain in the right elbow. His physical exam revealed no other signs nor symptoms and the neurological exam was normal. During recompression, symptoms disappeared after 11 minutes 45 seconds at 60 fsw and did not recur. Treatment was completed according to Table 6, and the patient emerged with no signs nor symptoms of decompression sickness.

IMPRESSION: Type I decompression sickness, treated by recompression according to USN Table 6

## SUMMARY REPORT OF HYPERBARIC THERAPY

DATE: 17 JUNE 1988

PATIENT: --  
SEX: MALE

## REASON FOR TREATMENT: DECOMPRESSION SICKNESS, TYPE II

SUMMARY: Subject participated in research dive for DMD Protocol 88-06. Dive was HeO2 79/21 at 60 fsw for 70 minutes on 16 Jun 1988. Dive left surface at 0843 and reached surface at 1004. The dive was relatively uneventful. When seen by me at 1235 (plus 30 min), subject related that he had just experienced a transient funny feeling of the lateral right forearm that lasted a few seconds as a "sharp" sensation, but everything then felt normal. At two hours post dive (1200), subject still possible to define an area of the right forearm where the subject reported he could distinguish sharp from dull, but the degree of sharpness was decreased in the defined area. The remainder of the physical exam was normal for mental status, cranial nerve function, sensation, strength, reflexes and balance. AT ALL TIMES except the few seconds of transient spontaneous sharpness, the only time there was abnormal feeling was when the subject was tested by sharp object. Subject was recompressed to 60 fsw at 1212 (plus 2:10). There was partial relief of symptoms when examined during the first air break, and complete relief during the second air break. Treatment was completed according to US Navy Table 6, and no abnormalities were present after surfacing.

IMPRESSION: DECOMPRESSION SICKNESS, TYPE II, Successfully treated according to US Navy Table 6

#12

#11

# SUMMARY REPORT OF HYPERBARIC THERAPY

#14

DATE: 2 JUN 1988

PATIENT: SEX: MALE

## REASON FOR TREATMENT: DECOMPRESSION SICKNESS; TYPE I

SUMMARY: Subject participated in experimental dive to 60 feet for 100 minutes on HeO2 at 79/21. Experimental dive left surface at 1042 and reached surface at 1334. When evaluated at one hour post dive, subject reported he had had sharp pain in left hand that lasted one minute; this had occurred at plus 30 minutes after surfacing. There was no other problem until at 1430 (plus 2 hours) when subject had mild discomfort of left forearm just below elbow on medial volar surface. Neurologic exam revealed no other abnormalities. During recompression to 60 feet which started at 1449, subject had complete resolution of symptoms at 48 feet. Symptoms did not reappear. Treatment was completed according to US Navy Table 5. Patient was asymptomatic and had normal physical exam at 1710 (one hour after end of treatment).

IMPRESSION: Decompression Sickness, Type I; successfully treated with Table 5



# SUMMARY REPORT OF HYPERBARIC THERAPY

#14

DATE: 14 December 1988

PATIENT: STATUS: ACTIVE DUTY  
RANK/RA-

## REASON FOR TREATMENT: DECOMPRESSION SICKNESS, TYPE II

SUMMARY: This 33 year-old, male US Navy diver participated in Research Protocol 88-06A entitled "Improved Decompression Procedures for Free-Swimming Divers II." The dive was in water at 60 fsw for 120 minutes while in wet suit and breathing He/O2 at 79%/21% with Superlite 17 Breathing Apparatus. The divers left surface at 1428 and reached surface at 1631 on 12 Dec 1988. This subject developed redness and itching of the skin on the upper and right lateral abdomen. The rash started about 30 minutes after surfacing and gradually diminished until it was gone 2 h after surfacing. About three h after surfacing he developed pain in the left knee. He took 800 mg of Ibuprofen. Later the pain became worse and he developed nausea and light-headedness without vertigo. Some pain developed over the left hip beginning lateral to the spine and spreading laterally and downward over the left buttocks. When seen at 2130 (5 h after surfacing) he described the pain as above with the most severe pain being in the left knee. The pain at the knee was described as deep and extending along the lateral side of the knee for about 20 cm covering equal segments of the femur and tibia. The pain over the buttocks was described as sharp. Physical exam revealed increased sensitivity to touch over the affected areas with intact ability to discriminate light touch, sharpness and dullness. Anal wink was intact. Mental status was normal and all other sensory areas functioned normally. Muscle strength was equal to that before the dive with the exception of decreased strength of the left lower extremity that may have been due to pain. Deep tendon reflexes were intact, equal bilaterally, and unchanged from before the dive. There were no pathologic reflexes. At the end of the exam, the subject reported the onset of some numbness in the lateral part of the left foot. He was recompressed to 60 fsw and breathed oxygen. Relief of symptoms started as soon as recompression was underway; there was some residual at 10 minutes (primarily in the knee), and symptoms were completely gone by the end of the first 20-minute oxygen breathing period. Physical exam was normal when done during the first period on air. Treatment was completed according to US Navy Table 6. There was no recurrence of symptoms during nor after treatment. The patient is advised to avoid flying for 48 h and to avoid diving for four weeks. He

Page 4

#14

must be reevaluated by a diving medical officer before he resumes diving.

IMPRESSION: Decompression Sickness - Type II: Successfully treated according to US Navy Treatment Table 6

*[Signature]*

Dive with Spinal 2

# SUMMARY REPORT OF HYPERBARIC THERAPY

#19

DATE: 6 JUNE 1988

PATIENT

SEX: MALE

## REASON FOR TREATMENT: TYPE I DECOMPRESSION SICKNESS

SUMMARY: This patient participated in a dive for research protocol 88-06. The dive required 100 minutes of bottom time at 60 fsw with intermittent periods of exercise at 100 watts on a cycle ergometer. The divers left the surface at 0738 and reached surface at 0930 on 2 Jun 1988. Breathing media was 79/21 helium/oxygen. Pre-dive history and physical revealed no abnormalities and no reason to not participate in the dive. This diver reported no abnormalities after the dive surfaced. At 0800 on 3 June (plus 21.5 hrs after surfacing) he reported a noticeable pain in the right elbow, in the distal one-third of the forearm and in the PIP joint of the right index finger. He had had "normal aches and pains" after the dive. Physical examination revealed no other abnormalities; neurological examination was totally normal except for the reported pains described above. He was recompressed to 60 fsw and experienced complete relief of symptoms after four minutes at that level. Treatment was completed according to US Navy Table 5, and the patient surfaced with no recurrence of symptoms.

IMPRESSION: Type I decompression sickness, treated successfully according to USN Table 5.

*[Signature]*

## SUMMARY REPORT OF HYPERBARIC THERAPY

DATE: 24 MAY 1988

PATIENT:

SEX: MALE

#21

## REASON FOR TREATMENT: TYPE I DECOMPRESSION SICKNESS

SUMMARY: This patient participated in a dive for research protocol 88-06. The dive required 120 minutes of bottom time at 60 fsw with intermittent periods of exercise at 100 watts on a cycle ergometer. The divers left the surface at 0911 and reached surface at 1122. Breathing media was 79/21 helium/oxygen. Pre-dive history and physical revealed no abnormalities and no reason to not participate in the dive. There were five divers in the protocol. This patient plus two others subsequently developed symptoms that were diagnosed as Type I decompression sickness and all were treated under USN Treatment Table 6 beginning at 1243 (81 minutes after surfacing).

At 1135 (+17 minutes) this patient complained of pain in the right elbow that "came and went". At 1145, the right shoulder was involved, but the discomfort still was intermittent. There were no other neurologic abnormalities. At 1151 the discomfort was diminishing. During the process of evaluating this patient and the others who had complaints, this patient developed pain in the right knee just before recompression began. His physical exam revealed no other signs nor symptoms and the neurological exam was normal. During recompression, symptoms disappeared after two minutes at 60 feet and did not recur. Treatment was completed according to Table 6, and the patient emerged with no signs nor symptoms of decompression sickness.

IMPRESSION: Type I decompression sickness, treated by recompression according to USN Table 6



## SUMMARY REPORT OF HYPERBARIC THERAPY

DATE: 26 October 1988

PATIENT:

STATUS: ACTIVE DUTY USN

RANK/DATE: BMCS (DV)

#21

## REASON FOR TREATMENT: TYPE I DECOMPRESSION SICKNESS

SUMMARY: This patient participated in a dive for research protocol 88-06. The dive was 60 fsw for 70 min in the wet pot with subjects in wet suits and breathing He/O2:79/21. Divers left surface at 1023 and reached surface at 1137 on 24 Oct 1988. Patient had no complaints when seen at plus 0.5 and at 2.0 h post surfacing. During the evening of the day of the dive, he recognized pain in both elbows that recurred intermittently. It was neither relieved nor exacerbated by movement of the arm or forearm. He slept well but recognized symptoms after waking on 25 Oct. When seen at 0940, he reported the pain was gone for the past hour. When seen at 1300 on 25 Oct he reported that there had been some recurrence of pain but none since 1030. At 1515 he reported pain was still present. Physical exams done at 0940 and at 1515 on 25 Oct revealed no abnormalities. All findings were subjective reports by the patient. At 1515 it was decided that the subject had Type I decompression sickness and required treatment with recompression. The patient had complete relief of symptoms within 5 minutes after recompression started. Treatment was completed without complication according to Treatment Table 6 of the US Navy Diving Manual. Patient was still asymptomatic when seen at 0900 on 26 October 1988. It is recommended that he should avoid diving for at least two weeks.

IMPRESSION: TYPE I DECOMPRESSION SICKNESS TREATED SUCCESSFULLY. ACCORDING TO USN TABLE 6



Page 2

## SUMMARY REPORT OF HYPERBARIC THERAPY

DATE: 6 JUNE 1988

PATIENT:

SEX: MALE

## REASON FOR TREATMENT: TYPE II DECOMPRESSION SICKNESS

**SUMMARY:** This patient participated in a dive for research protocol 88-06. The dive required 100 minutes of bottom time at 60 fsw with intermittent periods of exercise at 100 watts on a cycle ergometer. The divers left surface at 1042 and reached surface at 1234. Breathing media was 79/21 helium/oxygen. Pre-dive history and physical revealed no abnormalities and no reason to not participate in the dive. Four minutes after he reached the surface, this patient reported tingling in the left shoulder and biceps area. The area involved gradually spread to involve the rest of the arm, then the thoracic area to below the scapula posteriorly and the nipple anteriorly, and then the anterior aspects of the thigh and leg, all on the left. The sensation was decreased sensitivity to sharp stimulus. There was no apparent change in strength nor deep tendon reflexes. Mental status and cranial nerves were not affected. Recompression to 60 fsw was started at 1254 (plus 30 minutes). Some relief was present during travel at 8 fsw, especially in the lower extremity. Improvement was gradual with return to normal occurring in the reverse order in which symptoms had developed. The last area to improve was the left shoulder where complete resolution of symptoms by physical exam had occurred at 1726. At that time there had been three extensions at 60 fsw and he had completed his first period of oxygen breathing at 30 fsw. There was no recurrence of symptoms. Treatment was completed according to US Navy Table 6 with three extensions at 60 fsw and two extensions at 30 fsw. The last two air breaks at 60 fsw were 10 vice 5 minutes. When he surfaced from treatment, he reported he could tell something had been wrong with his shoulder, but there was no detection of difference by physical exam. He was hospitalized overnight at NHBETH where examination by staff and resident physicians and chest X-Ray revealed no abnormalities. The next day (3 Jun) he still had the subjective feeling that something had been wrong, but physical exam was normal. He was sent home with instructions to return if symptoms recurred and to avoid strenuous activity. On 6 Jun 1988, he reported complete resolution of symptoms and was able to engage in regular physical training without difficulty.

IMPRESSION: Type II decompression sickness, successfully treated by recompression according to USN Table 6 with three extensions at 60 fsw and two extensions at 30 fsw

# SUMMARY OF HYPERBARIC TREATMENT

#26

Date of Treatment: 15 December 1988

On 14 December 1988 the patient surfaced from an uneventful "No D" dive to 60 fsw for 120 minutes breathing a 79/21 mix of HEO2 as a participant in NMR1 protocol 88-06A. After the thirty minute check the patient began to complain of left SI joint pain which began at depth while riding the bike. He denied any neurologic symptoms and admitted to a history of lower back pain. At the 2 hour check he was without complaints. At 2230 I was called to evaluate complaints of a pruritic rash. The itching was intense initially and was localized to the left shoulder posteriorly. The patient noted a red, non-raised rash in the same area. No other complaints were noted at this time. On exam the patient was found to have a 3x5 patch of erythematous, punctate rash which was not raised. The area had some bluish discoloration due to old scarring. A neuro exam was performed and found to be normal. After 15 minutes of observation the itching and rash had improved and no recompression was initiated.

At 0830 on 15 December 1988 the patient complained of left shoulder pain lasting greater than 10 minutes as well as other fleeting, transient niggles. He also complained of decreased sensation of the left lateral aspect of the small finger distal to the distal interphalangeal joint. As the exam progressed the patient stated that both the shoulder pain and the sensory change had subsided. On exam his skin in the region of his right and left shoulder and right forearm had a mild erythematous rash. The neurologic exam was normal including sensory examination of the left pinky finger. A scar was noted on the left pinky finger in the region of his alleged sensory changes. Psychomotor testing was performed and was found to be unchanged from baseline studies.

Due to the continuing nature of the patient's complaints a TT5 was performed. No subjective or objective benefit was obtained from the TT5.

IMPRESSION: Migratory complaints not related to decompression sickness. No relief with U.S. NAVY Treatment Table 5.

*Dr. M. Stevens*

# SUMMARY REPORT OF HYPERBARIC THERAPY

#36

DATE: 12 January 1989

PATIENT: ACTIVE DUTY  
RANK/RATE: BUC(DV)  
SSN:

REASON FOR TREATMENT: SUSPECTED DECOMPRESSION SICKNESS, TYPE I

SUMMARY: This 36 year-old, male US Navy diver participated in Research Protocol 88-06B entitled "Improved Decompression Procedures for Free-Swimming Divers II." The dive was in water at 60 fsw for 300 minutes while in wet suit and breathing N2/O2 at 60/40 with Superlite 17 breathing apparatus. The divers left surface at 0825 and reached surface at 1331 on 11 Jan 1989. When seen at 1400 and 1530 (.5 and 2 h post dive), he complained of shoulder pain that involved both shoulders and the back and posterior neck. There was no abnormality of neurologic function either subjectively or by physical exam. During the rest of the afternoon and evening, all discomfort decreased except that there continued to be a deep pain in the left shoulder. When reevaluated at 0730 on 12 January (18 h post dive), the pain in the left shoulder was still present. There was no abnormality in sensory function nor in any other part of the neurological exam. The pain was described as deep, constant but waxing and waning and not exacerbated by movement nor palpation. He was compressed to 60 fsw and treated according to treatment table 5; there was no relief at any time during treatment. After treatment ended, the pain and examination were the same as before treatment. Twenty-four hours after treatment, the pain had disappeared.

IMPRESSION: Shoulder pain related to activity, most likely caused by prolonged wearing and use of harness for breathing apparatus.

*Dr. M. Stevens*

## E. Materials

This section describes the materials used to prepare this report. Relevant data are included with the report.

### 1. Material supplied as part of this project

- a. Data Report (this text)
- b. Compact disk with files (maintained at NMRC)
  - PDF file of the report
  - WordPerfect file of the report
  - Data base file NMRNSW2
  - Thalmann's original notes as Excel file: nmri\_8806\_results.xls.
- c. Diver ID "key" showing names and ID numbers of diver subjects (maintained at NMRC)

### 2. Materials used in preparing this report

Pages copied from conventional dive log  
Original Human Research Protocol for 88-06, NMRI  
Original Human Research Protocol for 88-06A, NMRI  
Case narrative reports of medical officers, 18 narratives  
References listed below

## F. References

Temple DJ, Ball R, Weathersby PK, Parker ED, Survanshi SS. 1999 May. The dive profiles and manifestations of decompression sickness cases after air and nitrogen-oxygen dives. Vol. I: Data set summaries, manifestation descriptions, and key files. NMRC 99-02 (Vol. I). Bethesda: Naval Medical Research Center (NMRC). Section I.J. NMRNSW2 [This is the "Manifestations" report].

Thalmann ED, Survanshi SS, Flynn ET. 1989 Jun. Direct comparison of the effects of He, N<sub>2</sub> and wet or dry conditions on the 60 fsw no-decompression limit. Undersea Biomed Res 16 (Suppl): 67.

Weathersby PK, Survanshi SS, Nishi RY, Thalmann ED. 1992 Sep. Statistically base decompression tables VII. Selection and treatment of primary air an N<sub>2</sub>-O<sub>2</sub> data. NSMRL Report 1182/NMRI Report 92-85. Bethesda, MD: Naval Medical Research Institute. Page B-8, C16-C17. [This is the "SBDT VII" report.]



## **APPENDICES**

### **Appendix A**

A-1. Extract from Protocol 88-06, dated 1988 May 02.

A-2. Extract from Protocol 88-06A dated 1988 Sep 16.

### **Appendix B**

Abstract from UHMS, presented at meeting in Honolulu, 1989 June.

### **Appendix C**

Extract from Volume I of the Manifestations report, 1999 May.

### **Appendix D**

Extract from Report VII of the Statistically Based Decompression Tables series, 1992 Sep.

## APPENDIX A-1. Extract of original protocol for Project 88-06, dated 88May12

## Improved Decompression Procedures for Free-swimming Divers II

This extract contains primarily the components of the original protocols that relate to the decompression aspects of the project. Matters such as ethical treatment of subjects, resource planning, scheduling, watches, approval, etc., have been left out. Pen and ink changes are incorporated. Some original page numbers are left in place.

## 1.0 OBJECTIVES

## 1.1 Background/Objectives

NMRI was tasked by the Chief of Naval Operations (Code 31) to investigate improving decompression procedures for free-swimming divers. The first phase of this was completed in 1986 according to NMRI Protocol 86-03. In this study, the maximum extension of no-decompression limits breathing 40% O<sub>2</sub> in helium was investigated. Successful dives of up to 8 hours duration were accomplished. Also, in 1983 a series of N<sub>2</sub>-O<sub>2</sub> dives breathing various O<sub>2</sub> fractions indicated that significant extension of N<sub>2</sub>O<sub>2</sub> decompression limits was possible (NMRI Protocol 83-01).

This study will be a follow-up to the two studies above and will seek to answer three questions:

1. Can the increased N<sub>2</sub>-O<sub>2</sub> no-decompression limits predicted by the Weathersby study (Protocol 83-01) be attained?
2. What is the no-decompression advantage of using helium instead of nitrogen as an inert gas, and is the advantage operationally significant?
3. How much does breathing air after completing a no-decompression dive on HeO<sub>2</sub> contribute to the longer HeO<sub>2</sub> no-decompression limits?

All dives will be at 60 fsw using either a 21% or 40% oxygen fraction. The starting no-decompression times will have been based on analysis of earlier dives and these will be incrementally extended up to a pre-determined maximum time if no decompression sickness (DCS) is encountered. Full details are found in Annex A.

## 2.0 Medical requirements

Divers will have had an experimental diving medical examination within the past year in accordance with MANMED 15-36.

All divers will have had the NMRI DNTB neuropsychologic testing battery as a baseline.

## 2.2 Alcohol/Medications

To avoid masking the symptoms of DCS, no subject will consume more than 2 ounces of alcohol 24 hours before and after any dive.

Diver-subjects will notify the DWMO of any medication (prescription or nonprescription) consumed 24 hours before any dive.

2. What is the no-decompression advantage of using helium as an inert gas over nitrogen and is the advantage operationally significant?

3. How much does the post-dive gas switch to air after diving on HeO<sub>2</sub> contribute to the longer HeO<sub>2</sub> no-decompression limits?

All dives will be performed at a depth of 60 fsw and two oxygen fractions (21% and 40%) will be investigated with either helium, or nitrogen as the inert gas. In order to maximize the number of data points, the initial phases of the study will be performed using dry chamber dives allowing 5 man-dives per run. After establishing no-decompression limits on dry dives, a series of wet dives will be performed to verify these limits under more realistic operational conditions. Using wet dives, the number of man-dives per run will be reduced to 2-3.

P. A-6

The overall design of the study will be sequential. Testing will begin at no-decompression limits presumed safe and will progress to the next longer time if there is no DCS in 10 man-dives. The maximum time to be tested if no DCS occurs will be specified in advance. If there is only a single case of Type I DCS in 10 man-dives, another 10 will start at that time. Progression to the next longer time will be initiated only if no further DCS occurs. If additional DCS does occur, then testing will stop and the previously tested time be the maximum no-decompression limit.

Intermittent exercise at an oxygen consumption of 1-1.5 l/min will be done for approximately one-half of the total bottom time. Exercise will stop at least 5 min before direct ascent to the surface at the maximum chamber rate of travel, but not exceeding 60 fsw/min. When breathing the 40% O<sub>2</sub> gas mixes during dry chamber dives, gas will be supplied by BIBS mask; chamber atmosphere will contain the same inert gas being breathed with 21% O<sub>2</sub>. This is designed to eliminate significant inert gas exchange across the skin while keeping chamber oxygen well below maximum limits as dictated by fire safety considerations. After ascent to the surface is complete, divers will either breathe air or 79/21 HeO<sub>2</sub>. Since the post-dive breathing will be long (8-18 hrs), divers will be kept in the chamber that will have a 79/21 HeO<sub>2</sub> atmosphere. This will preclude wearing masks and allow them to sleep comfortably if they desire.

At completion of the study, the results will be incorporated into a decompression model that will form the basis for further testing and/or validation in the future.

### Methods

All divers will make a maximum of 1 dive/week with a minimum period of 144 hrs off between dives. No systemic drugs or other than antibiotics will be

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allowed. Divers will refrain from any alcohol intake of more than 2 oz. for the 24 hrs preceding and any dive he makes.

Divers will be interviewed each morning by a DWMO to verify their fitness to dive. After completion of each dive, the DWMO will interview the divers within 30 min, 2-3 hrs, and 8-18 hrs following the dive. Normal results need to be documented only after the final interview, but abnormal results will be documented immediately. Treatment of any DCS that arises will be in accordance with standard U.S. Navy procedures.

On dry chamber dives, there will be 5 subjects on each dive. During wet dives there will be 2-3 subjects and 2 dive tenders. Decompression procedures for the tenders are described below.

On dry chamber dives where helium is the inert gas, the chambers are initially flushed with helium until a nitrogen level of less than 1% is attained. This nitrogen level will not be exceeded for the duration of the dive or the HeO<sub>2</sub> post-dive period. If chamber N<sub>2</sub> exceeds 1.0%, divers will breathe 79/21 HeO<sub>2</sub> by mask until the problem is corrected.

All compressions will be at a rate not to exceed 30 fsw/min. On long dives (time > 240 min), the specified time will be from reaching 60 fsw to beginning ascent (i.e., descent time not included). On short duration dives (time ≤ 140 min) actual time at depth will be determined with the aid of the NMRI Version 1.0 Real Time Decompression Program. The algorithm used in the program will be adjusted to predict the specified time as being the maximum no-decompression time at 60 fsw for a 60 fsw/min descent rate. The program will be started and then compression to 60 fsw accomplished as close to 30 fsw/min as possible. Upon reaching 60 fsw, the program will continue to update the no-decompression time remaining at 60 fsw. Ascent to the surface will be started when the total decompression time equals 100 sec (i.e., a 50 sec stop at 10 fsw). Ascent to the surface will begin at that instant and a

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10 fsw stop will be taken only if the stop time shows more than 1 min. If the stop time is greater than 1 min, the diver's depth will be kept at 10 fsw until a stop time of 1 min remains at which point ascent to the surface will begin. This procedure will allow a systematic compensation for any delays in descent and should make all dives for a given planned duration comparable, while ensuring they are at the maximum planned no-decompression time.

Since some dry dives will require a 10 fsw stop during compression to eliminate helium from the chamber, all dives will include this stop to ensure comparability. Compression for all dry dives will begin with descent to 10 fsw, a stop there of 10 min, followed by compression to depth at 30 fsw/min. Wet dives require no such stop, therefore compression will be directly to depth.

Divers breathing gas and BIBS breathing gas will be sampled at various times during the dive to ensure that the proper gas mix is being administered. Gas will leave the chamber via the sample line and be analyzed at 1 ATA.

All BIBS masks will be set to give a small amount of free flow at end expiration to minimize breathing chamber atmosphere gas.

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### DRY DIVES

General: Dives will be performed under one of six conditions as shown in Table 5. The order of the studies will test all N<sub>2</sub>O<sub>2</sub> dives first (A and D), then HeO<sub>2</sub> dives with air breathed post-dive (B and E), and finally HeO<sub>2</sub> dives with 79/21 HeO<sub>2</sub> breathed post-dive C and F).

Exercise on all dives will be accomplished using three bicycle ergometers set to a work rate of 125 watts [changed from 100 W, 88May11]. Divers will alternately exercise in teams of 2 and 3 people for 10 min during short bottom time dives (Conditions A, B, C), and 20 min during long bottom times dives (Conditions D, E, F). On these long dives, the rest period will be increased to 40 min after every 3rd work period. The maximum number of work cycles for each possible bottom time is given in Table 6. This schedule ensures that all divers will have been at rest at least 1 full rest period before decompression begins.

Divers will be compressed on BIBS mask breathing 21% O<sub>2</sub> and the appropriate inert gas for all dives where air is not used for compression. Once at depth, and after establishing a chamber atmosphere of 21% O<sub>2</sub> in the appropriate inert gas, divers will either breathe 21% O<sub>2</sub> chamber atmosphere or breathe 40% O<sub>2</sub> mixes by mask. A maximum chamber CO<sub>2</sub> level of 0.5% SEV will be maintained at all times. Upon reaching depth, divers will begin the appropriate exercise schedule. If the number of work periods as specified in Table 5 cannot be done, then the Principal Investigator will advise the Dive Watch Officer on the appropriate adjustment.

After the appropriate interval at depth, ascent will take place at a rate as close to 60 fsw/min as possible. Upon arrival at 1 ATA, the divers will either leave the chamber if air is to be breathed post-dive, or will remain in the chamber breathing 21 O<sub>2</sub> in helium, as appropriate. Medical interviews will be conducted at times specified above and for post-dive air breathing

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dives. Upon surfacing, a "shadow" will be assigned to each diver. Shadows will stay with the divers one hour. Divers must stay on the operations floor until after the first interview by the DWMO [changed 88May12]. Divers

## Time/Depth/SAT profile

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Computer file names will be according to the following format:

NSWIYXX.PRO

Naval Special Warfare Dive Series 1

Y - Condition of dive from Table 5

XX - Sequence of dive in series -  
first dive will be 01.

After completion of the dive series all files will be transferred to magnetic tape, cataloged and stored permanently.

[Tables 1-4 are for planning; no results so not included here]

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Table 5  
Experimental Conditions

Condition	Starting Time (min)	Max Time (min)	Increment (min)
21% O <sub>2</sub>			
A - N <sub>2</sub> inert	70	100	10
B - He inert/air post-dive	120	140	10
C - He inert/79/21 HeO <sub>2</sub> 8 hrs post-dive	110	140	10
<hr/>			
40% O <sub>2</sub>			
D - N <sub>2</sub> inert	240	480	60
E - He inert/air post-dive	480	540	60
F - He inert/79/21 HeO <sub>2</sub> 14 hrs post-dive	420	540	60

Table 6  
Maximum Number of Work Cycles  
[for each diver; includes Change 3]

Bottom Time                      Short dives 10 min Work/10 min rest

70	3
80	3
90 or 100	4
110 or 120	5
130	6
140	6

Long Dives 20 min work/ 20 min rest - 40 min  
after every 3rd work cycle

240	5
300	6
360	7
420	9
480	10
540	11

## APPENDIX A-2. Extract of original protocol for Project 88-06A, dated 88Sep16

## Improved Decompression Procedures for Free-swimming Divers II

This is an extract of the modification of the original protocol for Project 88-06 to Project 88-06A. Many of the requirements that were not changed from 88-06 have not been included here. Pen and ink changes are incorporated. [Reporters comments are shown in square brackets.]

## 1.0 BACKGROUND, OBJECTIVES

## 1.1 Background

This protocol is a revision of Protocol 88-06, whose study was intended to be completed in two parts running from May-July and from Sept-Nov 1988. Upon completion of the first part of the protocol in July 1988, there were enough changes envisioned in the experimental procedures to warrant a protocol revision. The major changes involve (1), elimination of the dives where divers are kept in a helium atmosphere post-dive, and (2) addition of multiple level wet dives and 40 fsw no-decompression dives on air and 79/21 HeO<sub>2</sub>.

The initial part of the current study consisted of a series of dry no-decompression dives at 60 fsw breathing either air or 79/21 HeO<sub>2</sub> from chamber atmosphere. The results of this portion of the study that was completed in July 1988 showed that the no-decompression limit on air could be extended to 90-100 min, but that breathing 79/21 HeO<sub>2</sub> the no-decompression time was only 80 min. The no-decompression limit on HeO<sub>2</sub> was much shorter than reported in earlier work done at NEDU (NEDU Reports 1-59, 3-59) and the reason for this surprising result remains unclear. Since these dives were all dry with divers in a 79/21 HeO<sub>2</sub> or air chamber atmosphere, one possibility is that skin absorption played a more significant role than previously supposed. If this is so, then the no-decompression limit for in-water wet suit exposures, when no gas absorption will take place through the skin, should be longer than the dry exposures.

## 1.2 Objectives

This study, which is a continuation of the one described in Protocol 88-06, will seek to answer these questions:

1. Will the no-decompression limits established during dry dives breathing 79/21 HeO<sub>2</sub> or air be safe to dive during wet exposures, and can they be extended?
2. How do the no-decompression limits using helium as the inert gas compare to those using nitrogen at depths other than 60 fsw (40 fsw and 100 fsw) and at elevated oxygen fractions (40%)
3. Do multiple level dives adversely effect the no-decompression limit?

Dives will use either air, 79/21 HeO<sub>2</sub>, 60/40 N<sub>2</sub>O<sub>2</sub>, or 60/40 HeO<sub>2</sub> as the breathing gas. Initially, dives will be done at 60 fsw and then at 40 and 100 fsw if time permits. Some dives will be wet, with divers totally immersed wearing full wet suits, while other dives will be dry chamber dives. No-decompression times will start in areas presumed safe from previous experience and incrementally extended up to a predetermined maximum time if no decompression sickness (DCS) is encountered. Full details are found in Annex A.

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## 5.4.5 Divers Gas System Gases

The divers gas system will be lined up in accordance with OP 12.2.1. Breathing mixtures will be switched in accordance with OP 14.2.1 (Gas Changing). The underwater breathing apparatus will be either AGA full face masks, Superlite 17's, or Mk-1 masks. Mixtures to be breathed will be either Air, 79/21 HeO<sub>2</sub>, 60/40 N<sub>2</sub>-O<sub>2</sub>, or 60/40 HeO<sub>2</sub> depending on the dive conducted.

## 5.7 Environmental control

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5.7.1. a. Dry Chamber Dives

(1) The normal limits of chamber O<sub>2</sub> concentrations will be between 20.5% (low) and 21.5% (high). If the O<sub>2</sub> concentration falls below 20.5%, follow OP-10 to add O<sub>2</sub> via the bypass of OMS-14 until a level of 21.0% is reached; O<sub>2</sub> add should stop at this point to prevent overshoot. If O<sub>2</sub> exceeds 21.5%, but is not above 25% no action is required, as the chamber occupants will breathe down the O<sub>2</sub> level. Follow EP-1 when the O<sub>2</sub> level exceeds 25% and utilize another chamber to facilitate a vent. If a vent cannot be accomplished, then the dive must be aborted.

(2) If the O<sub>2</sub> reaches a partial pressure of 0.16 ATA or lower, all dry chamber occupants will don the emergency BIBS mask and EP-2 is to be followed.

b. Wet Chamber Dives

(1) During these dives all tenders will be breathing 60/40 N<sub>2</sub>-O<sub>2</sub> from the BIBS masks. UBA exhaust gases may be vented to chamber atmosphere, which will cause a rise in the chamber oxygen level for studies where divers breathe 40% O<sub>2</sub>. In all cases, chamber O<sub>2</sub> levels will not be allowed to exceed 30%.

## 5.7.3 Inert Gas Limits and Control

a. During dry chamber HeO<sub>2</sub> dives, N<sub>2</sub> levels in the chamber will be reduced to less than 0.5%.

b. During wet dives, no specific limits on chamber N<sub>2</sub> or He are established. All dry occupants will breathe from BIBS masks.

## 5.7.4 Temperature Control

Atmospheric temperature will be controlled through the ACS Loop to the comfort of the divers, but should not exceed 90 °F. The wet pot temperature will be maintained in accordance with Annex A.

## 5.7.5 Relative Humidity

Relative humidity will be controlled through the ACS Loop and maintained to the comfort of the divers, but not lower than 50%.

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## 5.10 Compression Phase

During wet dives, chambers will be compressed on air. When dry chamber dives are performed, the compression of the MRCC will be as specified in Annex A.

## 5.12 Decompression Phase

a. Decompression of the subjects will be as close as possible to, but not exceeding, 60 fsw/min.

b. During wet dives, dry tenders will breathe 60/40 N<sub>2</sub>-O<sub>2</sub> by BIBS mask. No-decompression limits will be determined in accordance with U.S. Navy mixed gas, SCUBA procedures by computing the Equivalent Air Depth (EAD) for 60/40 N<sub>2</sub>-O<sub>2</sub> and using the appropriate air no-decompression limits. When breathing 68/40 N<sub>2</sub>-O<sub>2</sub> these limits are as follows:

TABLE 5-1

Air

Study



<u>Chamber Depth</u>	<u>EAD</u>	<u>No-decompression Bottom Time Limits</u>		<u>No-decompression Bottom Time Limits</u>
60 ft		37	200	180
55 ft		33	310	270
40 ft		22	315	270
35 ft		18	325	270

NOTE: The study will involve diver depths of 40 and 60 fsw, but divers will generally be 5 fsw deeper than chamber depth since they will be in the wetpot.

## ANNEX A [to Protocol 88-06A]

**IMPROVED DECOMPRESSION PROCEDURES  
FOR FREE-SWIMMING DIVERS  
PHASE II (REVISED)**

Background (Unchanged from original)

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Results of Initial Testing:

The initial portion of testing involved no-decompression dives in the dry chamber breathing either air or 79/21 HeO<sub>2</sub>. The results are summarized in Table 5. The air dives went as planned with no DCS occurring until a substantial increase in bottom time had been achieved. When this occurred, an additional 10 man-dives were done at 90 min to further establish the safety of this limit. This no-decompression time is midway between the predicted limits given in Table 2. [These were done with VVAL71 and VVAL72.]

In contrast, a significant incidence of DCS was observed on the first HeO<sub>2</sub> dive at 130 min [Actually 120 min; it is 130 min only if the 10 min at 10 fsw is included.]. In light of the previous studies cited in Table 4, this was surprising. The bottom time was reduced 20 min but the DCS incidence was still unacceptable. Reduction of bottom time to 70 min resulted in only a single case of mild DCS and extension to 80 min proved safe. At 90 min, the DCS incidence began increasing dramatically.

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Table 5  
Dive Summary To Date

AIR [NSW1A]			
Sequence	Depth/Time	Man Dives.	Cases DCS
1	60/70	10	0
2	60/80	10	0
3,5	60/90	20	0
4	60/100	20	1
79/21 HeO <sub>2</sub> [NSW1B]			
3	60/70	18	1
4,6	60/80	20	0
5	60/90	10	3
2	60/100	20	5
1	60/120	5	3

NOTE: Sequence shows the order in which dives were done. Dives with two sequence numbers indicate that the initial 10 man dives were DCS-free in which case bottom times were extended. When DCS occurred at this longer bottom time, an additional 10 man dives were done at the original bottom time.

The surprising results when breathing HeO<sub>2</sub> caused a reassessment of the study objectives from those initially set forth in Protocol 88-06. It was decided to re-orient the study to see if the unexpectedly short no-decompression times breathing 79/21 HeO<sub>2</sub> were a result of the dives being dry, causing helium absorption through the skin. If this is true, then doing wet dives, when no helium can be absorbed through the skin, should allow extension of no-decompression times.

Furthermore, it was decided to investigate the effect of multiple level dives on the no-decompression time. Theoretically, if one dives to a particular depth for a time shorter than the no-decompression time, then following any surface interval one should be able to spend the remaining time up to the no-decompression limit at that depth and

still be able to ascend directly to the surface. Thus, one should be able to interrupt a dive with any number of surface intervals and still have a cumulative time at a particular depth up to the single dive no-decompression limit.

Finally, it was decided to extend the no-decompression limit determination to 40 fsw. When breathing a 21% O<sub>2</sub> mix, the inert gas tension at 40 fsw (1.75 ATA) is just slightly more than when breathing 40% O<sub>2</sub> at 60 fsw (1.70). If only the inert gas tension is important in establishing the no-decompression time, then the no-decompression limit at 40 fsw breathing 21% O<sub>2</sub> and 60 fsw breathing 40% O<sub>2</sub> should be similar.

#### Proposed Study

The remainder of the study will consist of 4 parts:

1. Establishing no-decompression limits during wet exercise at 60 fsw breathing 79/21 HeO<sub>2</sub> or Air.
2. Establishing wet no-decompression limits at 60 fsw breathing 60/40 HeO<sub>2</sub> or N<sub>2</sub>-O<sub>2</sub>.
3. Verification of the 60 fsw no-decompression limits breathing 60/40 HeO<sub>2</sub> or N<sub>2</sub>-O<sub>2</sub> during multiple level dives. A-12
4. Establishment of dry-exercising no-decompression limits for air and 79/21 HeO<sub>2</sub> at 40 fsw.

Wet chamber dives will consist of 3 divers per run, while dry dives will use up to 6 divers per run.

The overall design of the study will be sequential. Testing will begin at no-decompression limits presumed safe and will progress to the next longer time, if there is no DCS in at least 9 man-dives. The maximum time to be tested, if no DCS occurs, will be specified in advance. If there is only a single case of Type I DCS in 9 man-dives, another 9 at the same depth and bottom time will start at that time. Progression to the next longer time will be initiated only if no further DCS occurs. However, if additional DCS does occur, then testing will stop and the previously tested time will be the maximum no-decompression limit.

If Type II DCS occurs in which the only symptoms are mild, subjective sensory changes, the study will progress as if it had been a Type I symptom. If Type II symptoms occur involving motor weakness and/or cerebral involvement, or if sensory changes are profound, then no further diving will be done at that bottom time, and the following dive will be reduced to the next shorter bottom time. The goal will be to perform at least 20 man-dives at the presumed maximum safe no-decompression time.

Intermittent exercise at an oxygen consumption of 1-1.5 l/min will be done for approximately one-half of the total bottom time. Exercise will stop at least 5 min before direct ascent to the surface. Ascent rate will be as close as possible to, but not exceeding, 60 fsw/min.

At the completion of the study, the results will be incorporated into a decompression model that will form the basis for further testing and/or validation in the future.

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The planned bottom times for all dives are given in Table 6. The bottom times for wet dives breathing 21% O<sub>2</sub> start 10 min less than the previously established dry limit. The maximum times will be those predicted by VVAL71 for air (Table 2) and the maximum time tested by Duffner and Snyder breathing 20% O<sub>2</sub> in He (Table 4).

The bottom times for the 60/40 N<sub>2</sub>-O<sub>2</sub> wet dives will begin at a time established safe by Weathersby at 74 fsw (Table 1) and increase in 60 min increments. The starting time for the 60/40 HeO<sub>2</sub> dives will be that previously shown safe by Smith et al. from a previous NMRI study. The planned bottom times for the 40 fsw dry dive breathing air will be the same as that shown safe by Weathersby at 35 fsw breathing a 12% O<sub>2</sub> in N<sub>2</sub> mix. Since the nitrogen partial pressure of air at 40 fsw is similar to that breathing 40 % O<sub>2</sub> in N<sub>2</sub> at 60 fsw, it is expected that the no-

decompression limits will be similar. Since 79/21 HeO<sub>2</sub> showed no advantage over air during dry dives at 60 fsw, the bottom times for HeO<sub>2</sub> at 40 fsw will be the same as for air.

### Methods

All divers will make a maximum of one dive per week with a minimum of 132 hours off between dives. No systemic drugs other than antibiotics will be allowed unless cleared with the investigator. Divers will refrain from any alcohol intake of more than 2 oz. for the 24 h preceding any dive he makes.

Divers will be interviewed each morning by a DWMO to verify their fitness to dive. After completion of each dive, the DWMO will interview the divers within 30 min, at 2-3 hrs, and again at 8-18 hrs following the dive. Normal results need to be documented only after the final interview, but abnormal results will be documented immediately. Treatment of any DCS that arises will be in accordance with the U. S. Navy Diving Manual.

On dry chamber dives, there will be up to 6 subjects on each dive.

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During wet dives there will be 2-3 subjects and 2 dive tenders.

All depths referred to in this annex are diver depth. During dry dives this will be chamber depth. On wet dives, the depth offset to compensate for the actual diver depth below the surface of the wetpot will be added to chamber depth to get diver depth. Depth offset is defined as the distance from the surface of the wetpot chamber/water interface to a point 6' above the grating at the bottom of the wetpot.

Compression rate will be at a rate as close to 30 fsw/min as possible. The tolerance for reaching depth within  $\pm 30$  sec of the calculated time assuming a rate of 30 fsw/min. Any deviations from this will be brought to the attention of the investigator immediately.

During compression and decompression all times will be logged to the second. Time of reaching and leaving depth will also be recorded to the second.

Decompression will be at a rate as close to 60 fsw/min as possible and recorded on an x-y plotter pressure plot. Each plot will be labeled with date and time, and given to the investigator.

### Wet Dives

All divers will wear a demand UBA and full 1/4" wet suits. Water temperature will be adjusted as follows, based on total dive time.

70 - 140 min	60° F
240 - 360 min	65° F
>360 min	70° F

In the water, exercise will be performed at 100 watts on 70-360 min dives; on 360 min dives the work rate will be reduced to 75 watts. This is 25 watts less than used during the dry dives, which compensates for moving legs through water. [Inserted text, change 4]

On short dives (<130 min) divers will have pre- and post-dive rectal temperatures measured. On long dives, divers will wear a rectal probe and in some cases will be instrumented with heat flow discs to measure heat flux while submerged.

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### Single Level Wet Dives

Divers will dress, don hat, and point zero time will begin. Divers will enter the wetpot and remain at the surface with their heads awash. UBA checkouts will be completed on research gas (Air, 79/21 HeO<sub>2</sub>, 60/40 N<sub>2</sub>-O<sub>2</sub>, or 60/40

HeO<sub>2</sub>. Compression will begin between +30 and +60 sec at a rate of 30 fsw/min. Divers will remain at the surface of the wetpot during compression to a chamber depth equal to diver depth (Table 6) less depth offset. One minute after arrival at depth, on a signal from the dive supervisor, the divers will descend to the bottom of the wetpot. Divers will then begin the appropriate exercise protocol, stopping work 5 min before decompression. [Text inserted and deleted, Change 2]

Note: During the 360 min (and longer) dives the following will be accomplished.

- a. During the first rest period after 3 hours, diver surfaces to the chamber, removes hat, and goes on hookah.
- b. [Notes illegible; "... water exactly 8 minute." this Note is Change 5]

Divers will remain at the bottom of the wetpot when decompression begins. Decompression will be at a rate as close to 60 fsw/min as possible. As chamber depth reaches 4 fsw, all divers will leave the bottom of the wetpot in unison. At the surface, all divers will exit the wetpot, sit on the rim, and when directed by the DWS, remove their UBAs within 30 sec of each other. At this point zero time stops.

Bottom time for the four breathing gases are given in Table 6 and the exercise protocol in Table 7.

#### Multiple Level Wet Dives

These dives will be compressed exactly the same way as the single level bounce dives. The breathing media will be 40% O<sub>2</sub> in N<sub>2</sub> or He. The maximum safe no-decompression limit for 40% O<sub>2</sub> will be used as a basis for these dives. Divers will spend 4 intervals at depth, with each depth interval being exactly ¼ of the maximum no-decompression limit. The at-depth intervals will be separated by 15 min surface intervals. Ascent rates will be 60 fsw/min. Interval times at depth and on the surface will not include ascent or descent time. The final decompression to the surface will be the same as for single bounce dives.

#### Dry Dives

Divers will enter "0" chamber and check out their BIBS masks. At time zero, divers will begin breathing the research gas from their BIBS masks and the chamber will be compressed to 10 fsw on air for air dives and 100% He for HeO<sub>2</sub> dives. The chamber will remain at 10 fsw for 10 min. When doing HeO<sub>2</sub> dives, this time will be spent "layering" all nitrogen from the chamber. At zero time plus 10 min, compression to depth will occur at 30 fsw/min.

The remainder of the chamber complex will have previously been compressed to depth on air (for air dives) or HeO<sub>2</sub> (for HeO<sub>2</sub> dives). When compressed on HeO<sub>2</sub>, the chambers will have been layered such that chamber N<sub>2</sub> is less than 0.5%.

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Table 6  
Experimental Conditions

Single Level 60 fsw Wet

Condition	Starting Bottom Time (min)	Max Bottom Time (min)	Increment (min)	21% O <sub>2</sub>
A - N <sub>2</sub> inert	80	100	10	
B - He inert	70	120	10	
40% O <sub>2</sub>				
C - N <sub>2</sub> inert	240	480	60	
D - He inert	480	540	60	
Single Level 40 fsw Dry				
21% O <sub>2</sub>				
E - N <sub>2</sub> inert	240	480	60	
F - He inert	240	480	60	

NOTE: Specified times are all actual times at 60 fsw and do not include descent times.

At depth, the "O" to "R" door will be opened, the divers will exit "O" chamber and immediately begin to work if on an air dive.

On HeO<sub>2</sub> dives the "O" to "R" door will be kept open for 2 min, then shut. This should let a consistent amount of helium enter the remainder of the chambers. Divers will remain on BIBS until chamber O<sub>2</sub> is between 20.5 and 21.0%. The divers will mix the chamber atmosphere by waving towels. Pre-dive chamber O<sub>2</sub> should be adjusted such that the amount of helium entering the chamber when "O" to "R" door is opened will lower the chamber O<sub>2</sub> level to no lower than 20-20.5%.

The number of exercise bouts is determined by bottom time and are given in Table 7. Exercise will stop 5 min before beginning decompression. Decompression will be accomplished at a rate as close to 60 fsw/min as possible. The planned bottom times are shown in Table 6.

Post-Dive Procedures

After surfacing from a dive, divers will exit the chamber and a "shadow" will be assigned to each diver. The shadow must stay with the diver for 1 h. Divers will not leave the operations floor until the 30 min post-dive interview is completed by the DWMO. Divers will then remain in Bldg 53 until the 2-hour post-dive interview is complete. Divers must remain within 2 h travel time (by automobile) of Bldg 53 until the 12-18 hour interview is completed, which will generally be the morning following completion of the dive.

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Table 7

Maximum Number of Work Cycles  
(f or each diver)

<u>Bottom Time</u>	<u>Short dives, 10 min Work/10 min rest</u>
70	3
80	3
90 or 100	4
110 or 120	5
130	6
140	6

Long Dives 10 min Work/10 min rest

Half work cycles 5 min work/5 min rest [Ch #3, 89Jan04]

200-220	4
240	11 ½
300	14 ½
360	17 ½
420	20 ½
480	23 ½
420-460	10
460-500	11
500-540	12
540	13

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A-21

Decompression Sickness

Treatments of any suspected cases of DCS will be carried out according to the procedures outlined in Chapter 8 of the U.S. Navy Diving Manual.

Divers suffering only Type I DCS may resume diving in the study one week after completion of a treatment, if found fit to dive by the DWMO. Divers suffering Type II DCS will not dive for a minimum of 14 days and resume diving only on the recommendation of the DWMO.

A-22

Termination Criteria

When divers are wearing rectal probes, in-water exposures will be terminated if rectal temperature falls below 35°C.

Dive Records

Dive log entries will include the computer file name, ascent and descent times to the second, and barometric pressure before and after each dive and at 3 hour intervals during the dive.

The chamber depth and diver depth for all dives will be recorded and stored by a computer either once a minute or on a depth change greater than 2 fsw.

Computer file names will be according to the following format:

NSWIYXX.PRO

Naval Special Warfare Dive Series 1

Y - Condition of dive from Table 5

XX - Sequence of dive in series - first dive will be 01.

After completion of the dive series all files will be transferred to magnetic tape, cataloged and stored permanently.

### Progression of the study

Dives will be accomplished in the following sequence:

<u>Type of Dive</u>	<u>Depth</u>	<u>Max Man-Dives</u>
Short Wet Air	60 fsw	30
Short Wet 79/21 HeO <sub>2</sub>	60 fsw	75
Long Wet 60/40 N <sub>2</sub> -O <sub>2</sub>	60 fsw	39
Long Wet 60/40 HeO <sub>2</sub>	60 fsw	30
Multi-Level 60/40 N <sub>2</sub> -O <sub>2</sub>	60-0 fsw	12
Multi-Level 60/40 HeO <sub>2</sub>	60-0 fsw	12
Long Dry Air	40 fsw	30
Long Dry 79/21 HeO <sub>2</sub>	40 fsw	30
		258

A-23

The amount of time it will take to accomplish these dives will depend on the number of man-dives that can be accomplished each week. Currently, diving is scheduled to begin on 1988 September 12, and can run no later than 1988 December 16, a maximum period of 14 weeks. Time estimates for two different diving intensities are based on a maximum of 2 dives per day for the short 21% O<sub>2</sub> dives and 1 dive per day for the long dives. These estimates are given for two levels of available subjects.

These time estimates are worst case and assume all planned dives are completed to the maximum planned bottom times. In the event that all planned dives cannot be done, wet dives will have priority over dry dives.

<u>Type of Dive</u>	<u>Maximum Time</u>	
	<u>18 Subjects</u>	<u>24 Subjects</u>
Short Wet	6 wks	4½ wks
Long Wet	4½ wks	4½ wks
Multi-Level	1½ wks	1½ wks
Long Dry	<u>3½ wks</u>	<u>2½ wks</u>
	15½ wks	13 wks



## **APPENDIX B.**

### **Abstract from UHMS, presented at meeting in Honolulu, 1989 June**

Thalmann ED, Survanshi SS, Flynn ET. 1989 Jun. Direct comparison of the effects of He, N<sub>2</sub>, and wet or dry conditions on the 60 fsw no-decompression limit. Undersea Biomed Res 16(Suppl):67.

Thalmann ED, Survanshi SS, Flynn ET. 1989 Jun. Direct comparison of the effect of He, N<sub>2</sub>, and wet or dry conditions on the 60 fsw no-decompression limit. Undersea Biomed Res 16(Suppl): 67.

67

110. DIRECT COMPARISON OF THE EFFECTS OF HE, N<sub>2</sub>, AND WET OR DRY CONDITIONS ON THE 60 FSW NO-DECOMPRESSION LIMIT. E.D. Thalmann, S.S. Survanshi\*, and E.T. Flynn\*. Naval Medical Research Institute, Bethesda, Maryland 20814-5055. 14741

A series of 256 man-dives was done to a depth of 60 fsw to determine the no-decompression (no-D) times under four sets of conditions: Air-Dry, HeO<sub>2</sub>-Dry, Air-Wet, HeO<sub>2</sub>-Wet. HeO<sub>2</sub> dives used 21% O<sub>2</sub> and on dry dives the chamber was compressed on breathing gas. Exercise was performed for 1/2 the time at depth (10 min work, 10 min rest) on a bicycle ergometer. Dry workload was 125 watts; wet was 100 watts where the divers wore 1/4" full wetsuits in 60 deg F water. Results are given as man-dives/cases of decompression sickness (DCS). Times are exclusive of the 2-3 min descent times. Analysis of results using

	Actual Time at 60 fsw (min)					
	70	80	90	100	110	120
Air-Wet		14/1	21/2	13/2		
Air-Dry	10/0	10/0	20/0	20/1		
HeO <sub>2</sub> -Wet	18/1	9/0	17/0	10/0	9/0	12/2
HeO <sub>2</sub> -Dry	18/1	20/0	10/3	20/5		5/3

the method of maximum likelihood showed that dry HeO<sub>2</sub> dives had the highest chance of DCS of any condition, probably due to significant gas absorption through skin. Wet air

air dives had a significantly higher chance of DCS than dry air dives. On wet dives no significant effect of He vs air was shown but the large confidence limits suggested insufficient data rather than absence of an effect. While wet exercise invokes a higher decompression stress than dry exercise on air, the advantage of HeO<sub>2</sub> over air for no-D dives remains to be demonstrated.

(Supported by NMRDC Work Unit 63713N M0099.01A.1002)

## **APPENDIX C.**

### **Extract of Volume I of the Manifestations report, 1999 May**

Temple DJ, Ball R, Weathersby PK, Parker EC, Survanshi SS. 1999 May. The dive profiles and manifestations of decompression sickness cases after air and nitrogen-oxygen dives. Vol. I: Data set summaries, manifestation descriptions, and key files. NMRC 99-02(Vol. I). Bethesda: Naval Medical Research Center (NMRC). Section I.J NMRNSW2.

**SECTION I: SINGLE AIR DIVES****J. NMRNSW2**

- 91 dives: 5 DCS, 5 Marginal
- All dives were wet; water temperature 50-65° F
- Dives were conducted during the period May 1988 - January 1989
- Exercise - bicycle at depth 50% (10 minutes on, 10 minutes off)
- This data set is included in the report, Statistically Based Decompression Tables VII.
- Descriptions of DCS manifestations were obtained from the medical files, dive logs and treatment logs for this protocol.

No report was written upon the completion of this study. These dives were part of a 4-element study of helium vs. nitrogen and wet vs. dry. E.D. Thalmann was the Principal Investigator of this NMRI Protocol #88-06 entitled: "Improved Decompression Procedures for Free Swimming Divers II".

## SECTION I: SINGLE AIR DIVES

J. NMRNSW2

91 dives: 5 DCS, 5 Marginal

Profile #	Outcome	T <sub>1</sub> (mins)	T <sub>2</sub> (mins)	Signs & Symptoms
4	Marginal	122.6	182.6	Felt cold without shivering after surface; no symptoms at surfacing; 2 hrs post dive asymptomatic, reevaluate in AM; Following day reported transient "niggles" of shoulders about 3 hrs after dive, but no sequelae; was very tired. Asymptomatic at the 24 hr check. Dx: niggles
8	DCS	34.4	124.4	("symptoms c/w Type I DCS"). Felt chilled for last 3 min of dive; surfaced with no symptoms; asymptomatic 1.5 hrs post dive. Approx 2 hrs post dive complained of diffuse left upper arm pain increasing to 3/10 over 30 min and remaining constant thereafter; unaffected by movement or muscular effort; recalled no recent or intra-dive activity that could have caused the injury; unable to affect symptoms by external manipulation. Neuro normal. Complete resolution at 57 seconds at 60 FSW TT5
15	Marginal	123.5	193.5	Asymptomatic at surfacing and 2 hrs post dive; approx 3-3.5 hrs post dive complained of 20-30 minute pruritis over forearms bilateral with discoloration; pruritis is transitory, not increasing in severity over past 20 min; no joint discomfort or areas of paresthesias; resolved within 30 minutes
17	Marginal	14.4	34.4	Asymptomatic upon surfacing; 30 min post dive complained of pruritis over medial forearm [no indication of right or left] mild transitory and not associated with paresthesias, discoloration or joint aches; pruritis due to reperfusion and warming or wetsuit, not DCS. Resolved and no complaints 2 hrs later
19	DCS	34.1	97.1	No symptoms upon surfacing - left ear squeeze at 2' on descent; approx 1.5 hrs post dive complained of numbness right upper arm & hand, progressing over 10 min; no associated pain/weakness but triceps feels less reliable than normal; denies trauma during dive; Neuro WLN. Erythematous patchy rash right pectoral area. Dx: Type II DCS a subjective sensory deficit of right triceps and skin over extensive surface of right forearm, wrist, thumb and forefinger. Recompressed 2 hrs post dive; complete relief 20 min at 60 FSW. TT6
22	Marginal	120	1440	Niggles. No complaints upon surfacing; 2 hrs post dive transient itching, migratory without skin discoloration; no pains; at 24 hr follow-up complained of transient migratory aches and pains in muscles of extremities; nothing persistent. Feels muscular fatigue as though strenuous physical workout; played basketball this morning and now feels improved. Neuro WLN.
23	DCS	123.4	363.7	The dive progressed IAW the protocol and all divers had no complaints at both the 15 min and 2 hr checks. At 1830 this diver noted a dull ache in his right knee. At the onset of pain he was lying down. He stood up and noted a dull pain at 1/10 intensity. He tried to "walk it off" and performed household chores. The pain increased over the next hour to an intensity of 5/6. He called the DMO at home at 1930 and the recall was initiated. Diver was examined by DMO at 1945. The pain in his right knee was 5-6/10 and was obviously affecting his gait as he walked to the examination room. There was no swelling of the knee and the range of motion was full. The neurologic exam was unchanged from the pre-dive

23 (cont)				exam. (Awake and oriented. Cranial nerves 2 thru 12 intact. Sensory without deficit except over right lateral malleolus due to surgical scar. This sensory deficit was unchanged from prior to the dive. Motor strength was 5/5 and symmetric. Reflexes: 2+ patellar, brachioradialis and biceps. 0 triceps. Babinski maneuver elicited downward movement of the toes. Cerebellar was intact by finger to nose and heel to shin maneuvers. The gait was normal except for the favoring of the right knee. Toe, heel and tandem walk were normal and Rhomberg was steady.) The initial diagnosis was Type I Decompression Sickness affecting the right knee. The patient was orally rehydrated and given oxygen via face mask at the surface at 1018. Recompression on TT5 was started at 2029. Total relief of symptoms occurred after one minute and 48 seconds at depth on oxygen. The patient was treated on a straight TT5 and reached surface at 2244. During the treatment he consumed 64 fl oz of water and voided 800 cc of light yellow urine. Neurological exams performed throughout the treatment were normal. At the surface the patient remained symptom free. At follow-up 24 hrs post treatment the patient remained symptom free and without complaints.
25	DCS	124.3	514.6	Asymptomatic upon surfacing and at 2 hr post dive check; presented following morning complaining of 5/10 persistent throbbing pain in right knee since 8.5 hrs post dive; unaffected by movement or direct pressure; no trauma during or after dive; feels generally fatigued; Neuro WLN ( note: 3 hrs sleep night before dive; 4-5 hrs/night for previous several nights); complete relief by 10 min @ 60 FSW. TT5
28	DCS	12.7	37.7	Dive was uneventful and divers were OK at the 30 min check. At approx 35 min post dive this diver complained of a pain simulating muscle spasm of his left flank. He reported to sickbay. Over the course of 3-5 minutes his symptoms progressed to include paresthesias of the left side from the left toes to the left chest and back above the nipple line, muscle weakness of the left lower extremity (quadriceps 3/5 according to corpsman's exam, gait grossly affected), perioral numbness and drooling. In the chamber just prior to descent the patient felt lightheaded but denied true vertiginous symptoms. He did not lose consciousness. Due to the severity and rapid progression of symptoms a full neurologic exam was not performed on the surface. Recompression proceeded on 100% oxygen to 60 fsw (TT6). The patient had complete relief after 1 min at the bottom. Two extensions at 60 fsw were performed. At depth vital signs were BP 130/90, P 60 regular, and respirations 16/min. An 18 ga. IV was introduced and NS at a rate of 150 cc/hr was started following a 500 cc bolus. Decadron 10 mg slow IVP was given without incident. A full neurologic exam at 60 fsw was normal. Neuro exams performed just prior to leaving 60 fsw, upon arrival at 30 fsw and at the surface were normal. The patient voided just prior to leaving 60 fsw. Total I/O: 2700/1921. Prior to fluid resuscitation a spin hematocrit was 43. After reaching the surface the patient performed psychomotor testing. The results were unchanged from baseline. The patient was examined by the duty resident neurologist at NHBETH and no abnormalities were found. An IM dose of Decadron 6 mg was given. The patient was followed at NMRI with Q3h checks and the next morning he remained without complaints with a normal neurologic exam. Impression: Type II DCS most likely involving brain stem or cervical/upper thoracic spinal cord.
36	Marginal	30	55	No symptoms or problems when seen at 30 min after surfacing (surface time 1600). At 55 mins after surfacing he was sitting in conference room, became light-headed and vomited. He was able to walk to sick bay where examination revealed no abnormalities. BP was 118/86. His condition improved rapidly while in sick bay and he returned to the conference room. Because he appeared extremely tired sitting in the conference room, he was brought back to sick bay where he was examined. Exam still revealed no significant pathology. Assessment of fatigue and dehydration. No complaints at 24 hour check.

Profile #	Data Set Name	Outcome	# of Divers	Depth	Bottom Time	Ascent Time	T <sub>1</sub>	T <sub>2</sub>	Data Set Notations
1	nmrsw2	0.0	3	61.5	81.5	1.7			NSW1C01
2	nmrsw2	0.0	3	61.5	83.7	1.3			NSW1C02
3	nmrsw2	0.0	2	61.5	82.3	1.1			NSW1C03
4	nmrsw2	0.5	1	61.5	82.3	1.1	206.0	266.0	NSW1C03
5	nmrsw2	0.0	1	61.5	92.3	1.4			NSW1C04
6	nmrsw2	0.0	3	61.5	92.3	1.2			NSW1C05
7	nmrsw2	0.0	2	61.5	91.9	1.2			NSW1C06
8	nmrsw2	1.0	1	61.5	91.9	1.2	127.5	217.5	NSW1C06
9	nmrsw2	0.0	2	61.5	92.1	1.2			NSW1C07
10	nmrsw2	0.0	3	61.5	92.1	1.5			NSW1C08
11	nmrsw2	0.0	2	61.5	92.1	1.3			NSW1C09
12	nmrsw2	0.0	2	61.5	92.2	1.3			NSW1C10
13	nmrsw2	0.0	2	61.5	91.9	1.1			NSW1C11
14	nmrsw2	0.0	2	61.5	102.2	1.3			NSW1C12
15	nmrsw2	0.5	1	61.5	102.2	1.3	227.0	297.0	NSW1C12
16	nmrsw2	0.0	1	61.5	102.4	1.1			NSW1C13
17	nmrsw2	0.5	1	61.5	102.4	1.1	117.9	137.9	NSW1C13
18	nmrsw2	0.0	2	61.5	106.1	1.3			NSW1C14
19	nmrsw2	1.0	1	61.5	106.1	1.3	141.5	204.5	NSW1C14
20	nmrsw2	0.0	2	61.5	101.6	1.3			NSW1C15
21	nmrsw2	0.0	1	61.5	102.1	1.2			nsw1c16
22	nmrsw2	0.5	1	61.5	102.1	1.2	226.7	1546.7	nsw1c16
23	nmrsw2	1.0	1	61.5	102.1	1.2	226.7	467.0	nsw1c16
24	nmrsw2	0.0	2	61.5	92.2	1.2			NSW1C17
25	nmrsw2	1.0	1	61.5	92.2	1.2	217.7	608.0	NSW1C17

26	nrmnsw2	0.0	3	61.5	84.2	1.2		nswlc18
27	nrmnsw2	0.0	1	61.5	82.3	1.1		NSW1C19
28	nrmnsw2	1.0	1	61.5	82.3	1.1	96.1 121.1	NSW1C19
29	nrmnsw2	0.0	3	61.5	242.3	1.2		NSW1E01
30	nrmnsw2	0.0	3	61.5	242.2	1.5		NSW1E02
31	nrmnsw2	0.0	3	61.5	242.8	1.0		NSW1E03
32	nrmnsw2	0.0	3	61.5	302.2	1.4		NSW1E04
33	nrmnsw2	0.0	2	61.5	302.0	1.3		NSW1E05
34	nrmnsw2	0.0	2	61.5	304.3	1.1		NSW1E06
35	nrmnsw2	0.0	1	61.5	303.2	1.4		NSW1E07
36	nrmnsw2	0.5	1	61.5	303.2	1.4	337.8 362.8	NSW1E07
37	nrmnsw2	0.0	3	61.5	363.1	1.2		NSW1E08
38	nrmnsw2	0.0	3	61.5	363.2	2.3		NSW1E09
39	nrmnsw2	0.0	3	61.5	363.1	1.2		NSWE10
40	nrmnsw2	0.0	2	61.5	360.1	1.1		NSWE11
41	nrmnsw2	0.0	3	61.5	362.6	1.2		NSWE12
42	nrmnsw2	0.0	3	61.5	362.2	1.1		NSW1E13
43	nrmnsw2	0.0	3	61.5	363.9	1.1		NSW1E14
44	nrmnsw2	0.0	3	61.5	93.1	1.1		NSWF01
45	nrmnsw2	0.0	2	61.5	93.1	1.2		NSW1F02



## **APPENDIX D.**

### **Extract from Report VII of the SBDT series, 1992 Sep.**

Weathersby PK, Survanshi SS, Nishi RY, Thalmann ED. 1992 Sep. Statistically based decompression tables VII. Selection and treatment of primary air and N<sub>2</sub>-O<sub>2</sub> data. NSMRL Report 1182/NMRI Report 92-85. Bethesda, MD: Naval Medical Research Institute. Pages B-8, C16-C17.

Study: Thalmann, ED. Air-N<sub>2</sub>O<sub>2</sub>-HEO<sub>2</sub> wet/dry decompression study at NMRI. May 1988 - Jan 1989 Air and N<sub>2</sub>-O<sub>2</sub> wet dives ONLY

#### Pressure exposure

Dry or wet	wet
Previous exposure--repet?	only last 5 divers in data
how long to be clean?	min 2 day, details in App C
Descent rate	variable, but recorded for each
Bottom depth	60 fsw nominal (use 61.5 at chest)
how measured	chamber + water to divers chest (5.5 ft)
Bottom time	81 to 365 min
Ascent rate	60 fpm for some, recorded for all
Tot decompression time	no-D (1.5 to 2 min)
Surface interval	20 min for last 5
Recompression?	only for last 5 and treatment

#### Gas breathed

Air or 40% O<sub>2</sub> in N<sub>2</sub>

#### Other factors

exercise	bicycle, 50%, 1.1 lpm O <sub>2</sub>
subject background	USN staff divers
water temperature	50-65°F

#### Doppler monitoring done?

#### Results

how bends defined	symptoms, successfully treated
% bends	5 DCS, 5 marginal of 91 man-dives on 45 profiles
distribution	wrist, elbow, shoulder, knee pain
time of DCS	included for all except fatigue

**Comments:** 1. Obtained recorded profiles. Used NSWAIR to examine, format. Assemble later. Discrepancies resolved with EDT.

**Data file:** NMRNSW.DAT

Weathersby PK, Survanshi SS, Nishi RY, Thalmann ED. 1992 Sep. Statistically based decompression tables VII. Selection and treatment of primary air and N<sub>2</sub>O<sub>2</sub> data. NSMRL Report 1182/NMRI Report 92-85. Bethesda, MD: Naval Medical Research Institute.

NMRNSW							
NSW1c01	1	3	61.5	79.7	87.2		
NSW1C02	2	3	61.5	79.5	88.9		
NSW1C03	3	2	61.5	79.0	85.9		
NSW1C03	4 M	1	61.5	79.0	85.9	206.0	266.0
NSW1C04	5	1	61.5	89.4	111.1		
NSW1C05	6	3	61.5	90.1	97.3		
NSW1C06	7	2	61.5	90.0	97.5		
NSW1C06	8 D	1	61.5	90.0	97.5	127.5	217.5
NSW1C07	9	2	61.5	90.1	97.3		
NSW1C08	10	3	61.5	90.1	97.1		
NSW1C09	11	2	61.5	90.1	97.2		
NSW1C10	12	2	61.5	90.1	96.1		
NSW1C11	13	2	61.5	90.2	97.8		
NSW1C12	14	2	61.5	100.1	106.7		
NSW1C12	15 M	1	61.5	90.8	106.7	227.0	297.0
NSW1C13	16	1	61.5	100.1	107.9		
NSW1C13	17 M	1	61.5	100.1	107.9	117.9	137.9
NSW1C14	18	2	61.5	99.0	111.5		
NSW1C14	19 D	1	61.5	99.0	111.5	141.5	204.5
NSW1C15	20	2	61.5	100.0	108.6		
nsw1c16	21	1	61.5	100.1	106.7		
nsw1c16	22 M	1	61.5	100.1	106.7		
nsw1c16	23 D	1	61.5	100.1	106.7	226.7	467.0
NSW1C17	24	2	61.5	90.2	97.7		
NSW1C17	25 D	1	61.5	90.2	97.7	217.7	608.0
nsw1c18	26	3	61.5	80.1	89.3		
NSW1C19	27	1	61.5	79.7	86.1		
NSW1C19	28 D	1	61.5	79.7	86.1	96.1	121.1
NSW1E01	29	3	61.5	240.1	254.5		
NSW1E02	30	3	61.5	240.0	249.2		
NSW1E03	31	3	61.5	240.0	248.2		
NSW1E04	32	3	61.5	300.0	310.0		
NSW1E05	33	2	61.5	300.0	309.2		
NSW1E06	34	2	61.5	299.0	310.7		
NSW1E07	35	1	61.5	300.2	308.3		
NSW1E07	36 M	1	61.5	300.2	308.3		
NSW1E08	37	3	61.5	360.1	369.0		
NSW1E09	38	3	61.5	360.1	370.4		
NSWE10	39	3	61.5	360.1	367.1		
NSWE11	40	2	61.5	360.0	370.6		
NSWE12	41	3	61.5	360.2	374.0		
NSW1E13	42	3	61.5	360.1	367.9		
NSW1E14	43	3	61.5	360.0	368.6		
NSWF01	44	3	61.5	360.9	438.3		
NSW1F02	45	2	61.5	360.7	440.3		

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